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MATURATION OF FOOT AND ROOT TISSUE IN WHEAT PLANTS IN RELATION TO PENETRATION BY *OPHIOBOLUS GRAMINIS* SACC.[1]

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Introduction

Many investigators, Kirby (*8*) among others, state that the take-all disease of wheat frequently occurs in patches, and that there is a gradual shading off in extent of stunting around the border of the infected area, presumably due to the fact that these plants were attacked later. Davis (*4*) reported that plants inoculated with *Ophiobolus graminis* at seeding time are more extensively diseased than those inoculated later. Broadfoot (*3*) at this laboratory found that with plants grown in the greenhouse and inoculated at ten day intervals, those inoculated at seeding time were much more severely damaged than those inoculated later, and that those inoculated after 40 days were seldom damaged to any marked extent. The growth of associated fungi and bacteria was shown by Sanford and Broadfoot (*12*) to modify the virulence of *O. graminis,* but this factor alone does not seem to explain fully the difference in infection observed.

The present study was undertaken to determine whether chemical and morphological changes accompanying maturation of the foot of the wheat plant offer any explanation of the observed behavior, and to investigate penetration and infection phenomena in plants in post-seedling stages.

Material and Methods

This investigation has been carried out in part upon some of the same material upon which Broadfoot's results are based. This consists of plants from the University of Alberta's Elite selection of Marquis seed, grown in pots in the greenhouse during 1929 and 1930. Some pots were inoculated at seeding time with *O. graminis* grown on oat hulls, and others every ten days to maturity. Check plants were treated similarly but sterile oat hulls were added in place of the inoculum. Plants from each inoculation group were taken up every ten days. Roots obtained from diseased fields in Central Alberta examined during the 1929 Plant Disease Survey were also used. All were fixed and preserved in form-acetic-alcohol and embedded as needed.

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Many stains were tried, singly and in combination. In the latter part of the work combinations of safranin and gentian violet, and methyl green and gentian violet were resorted to entirely. Many sections were examined unstained.

General Morphology of the Foot of the Wheat Plant

According to Avery (*2*) the appearance of the primary root is closely followed by that of a pair of lateral roots, and this by a second pair just above the first. These seminal roots (figure 1, sr.) all arise from the vascular plate of the scutellar node (figure 1, sn). For about two weeks little or no elongation of the internodes takes place, then the internode immediately above the scutellar node (the subcoronal internode, or rhizome) elongates, raising the nodes above it to just below the level of the ground (figure 1, r). The length of this internode depends upon the depth of planting, and if planted very deeply more than one internode may make up the rhizome. Adventitious roots sometimes appear in the region between the divergence of the scutellum and that of the coleoptile.

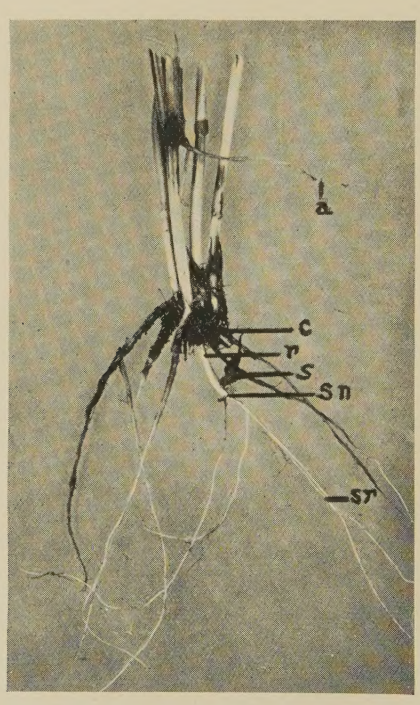

Figure 1. Base of wheat plant about 70 days old from the field, with some crown roots removed to expose other parts. (a) Adventitious root from lower node of culm, (c) crown, (r) sub-coronal internode, (s) first lateral shoot, (sn) scutellar node, (sr) seminal root.

Simmonds and Sallans (*13*) state that at three weeks from planting only three seminal roots have made their appearance, and by the sixth week the other pair have appeared, and in addition three crown roots. They mention a sixth seminal root which frequently does not appear,

but which does so in case of injury to others. By the ninth week 33 crown roots had appeared, and by the fifteenth week 59 were present. These latter have their origin in the crown, that is, the region just above the subcoronal internode where several nodes are crowded together, and from which the tillers and leaves also have their origin (figure 1, c). According to Percival (*11*) generally one pair of crown roots develops from each of the lower nodes of the primary axis and four or six from each of the higher nodes. Adventitious roots may also arise from the lower nodes of any of the tillers. Simmonds and Sallans' description is based on field material. In the greenhouse material used in this study, the crown roots developed earlier, the first ones being present at 20 days. Also the number at maturity is much smaller.

Weaver (*14*) states that, in the case of winter wheat at 30 days, the crown root system makes up 18 per cent of the total absorbing area, while Percival says that in crops sown in October and November, production of crown roots is delayed until the end of January, and that after this date they develop rapidly.

Anatomy and Maturation of the Foot of the Wheat Plant

Seminal Roots. A cross section of a seminal root near the scutellar node (Plate I. 1) shows the following tissues: a thin walled outer epidermis, a thin walled cortex of relatively great depth, a regular endodermis with uniformly much-thickened inner tangential and radial walls, a well marked pericycle consisting of a single layer of cells and a polyarch vascular cylinder with one or several large central vessels. In the roots examined, the primary root always had a solitary central vessel, while the other seminal roots had two or three.

In a plant 10 days old there is no sign of lignification[3] in the seminal roots indicated by the stains used, except possibly a trace in the spiral thickenings of the outer protoxylem vessels. The position of the xylem elements becomes complicated in the scutellar node (Plate I. 2), but at this age they show no evidence of lignification. In a plant 100 days old the xylem in both roots and node are much lignified. Some cells are plugged with a uniform, dark matrix, and the cortex shows signs of degeneration.

Crown Roots. The proximal centimetre of the third crown root of each plant was sectioned, and the tissues from plants of various ages compared. The age of the plant was used as a basis for determining approximately the relative ages of the tissue.

Crown roots have essentially the same structure as seminal roots, except that they have six to nine large xylem vessels, a polyarch stele with 10 to 20 protoxylem points, and the changes accompanying maturation are more marked.

In a plant 20 days old the endodermis is only slightly thickened and there is no evidence of lignification (Plate I. 3). In a plant 40 days old the endodermis has thicker walls, except opposite a few protoxylem points, and there is a hint of lignification in the protoxylem (Plate I. 4). In a plant 60 days old the vessels are thicker walled, and the endodermis

[3] Cell walls are herein referred to as "lignified" if they take the common lignin stains, e.g. safranin and methyl green. It is recognized that chemical changes other than the actual production of lignin may be responsible for this change in staining properties.

is much more pronounced (Plate I. 5). In addition the third, fourth, fifth and sixth layers of cells from the outside have become much thickened and somewhat lignified. In longitudinal section these cells are about three times as long as other cortical cells and the end walls are thickened to about the same extent as the side walls. Fellows (*5*) calls attention to this tissue and mentions that its development progresses from the proximal to the distal end as the root gets older. There are two layers of cells exterior to this sclerenchyma, the outermost of which (hypodermis) seems to be sloughed off with the root hairs (Plate I. 5, 6).

Older plants show no further change except perhaps a slight increase in the thickening of these lignified elements. The pericycle also becomes somewhat lignified, as also does some of the parenchyma between the protoxylem points.

Subcoronal Internode. The tissues of the subcoronal internode as seen in transverse section are shown in Plate II. 1, 4. They are: a single epidermal layer, a comparatively narrow band of thin walled cortical cells containing six or seven groups of sclerenchyma, more or less symmetrically placed near the periphery, an endodermal layer with much thickened inner tangential and radial walls, a stele composed of about 12 to 15 vascular bundles arranged approximately in two zones. The centre of the stele has always been filled with thin-walled pith cells.

In a plant 20 days old the endodermis is uniformly thickened and the sclerenchyma groups in the cortex are conspicuous, but there is little or no trace of lignification in the bundles. At 30 days there is a marked increased of lignification in the vessels and fibres of the bundle sheath. Henceforth little change takes place, except a slight increase in the thickness of the lignified elements (Plate II. 3, 4). There is no appreciable difference in structure throughout the length of the internode in any one plant, except sometimes an increase of two or three in number of sclerenchyma groups. The maturation of this internode seems to be continuous, thus differing from the higher internodes in which Athanassoff (*1*) states the process to be discontinuous.

Plate I. Maturation of root tissue of Marquis wheat plant. 1. Polyarch stele of primary root near scutellar node from a plant 10 days old showing much thickened endodermis (e), solitary large central vessels (c). There is little evidence of lignification. × 250.

2. Transverse section through scutellar node of plant 10 days old. × 70.

3, 4 and 5. Transverse sections through a crown root of plants 20, 40 and 80 days old, respectively, about 1 cm. from the crown. In the 20-day old plant the endodermis is only slightly thickened and there is no evidence of lignification. × 70. In the 40-day old plant the endodermis (e) is slightly thickened, except opposite a few protoxylem points, and there is a trace of lignification in the protoxylem (p). × 70. In the 80-day old plant, the endodermis is thicker and fibre vascular sheaths are thick and lignified. The subepidermal layers (sc) of the cortex are much thickened and lignified. × 70.

6. A higher magnification of the subepidermal layers (sc) in a root from a plant 70 days old. × 250.

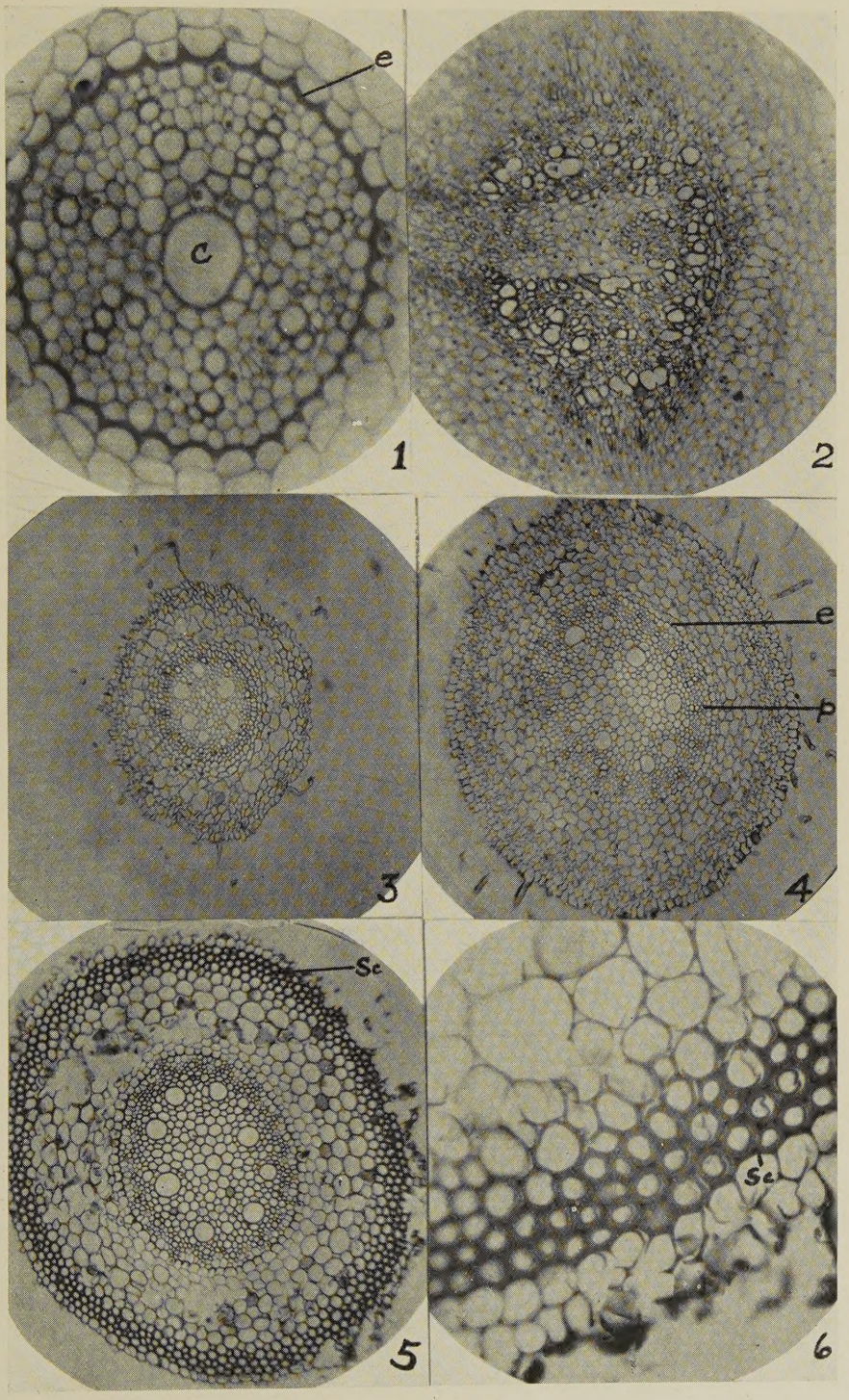

PLATE I. *See foot of opposite page.*

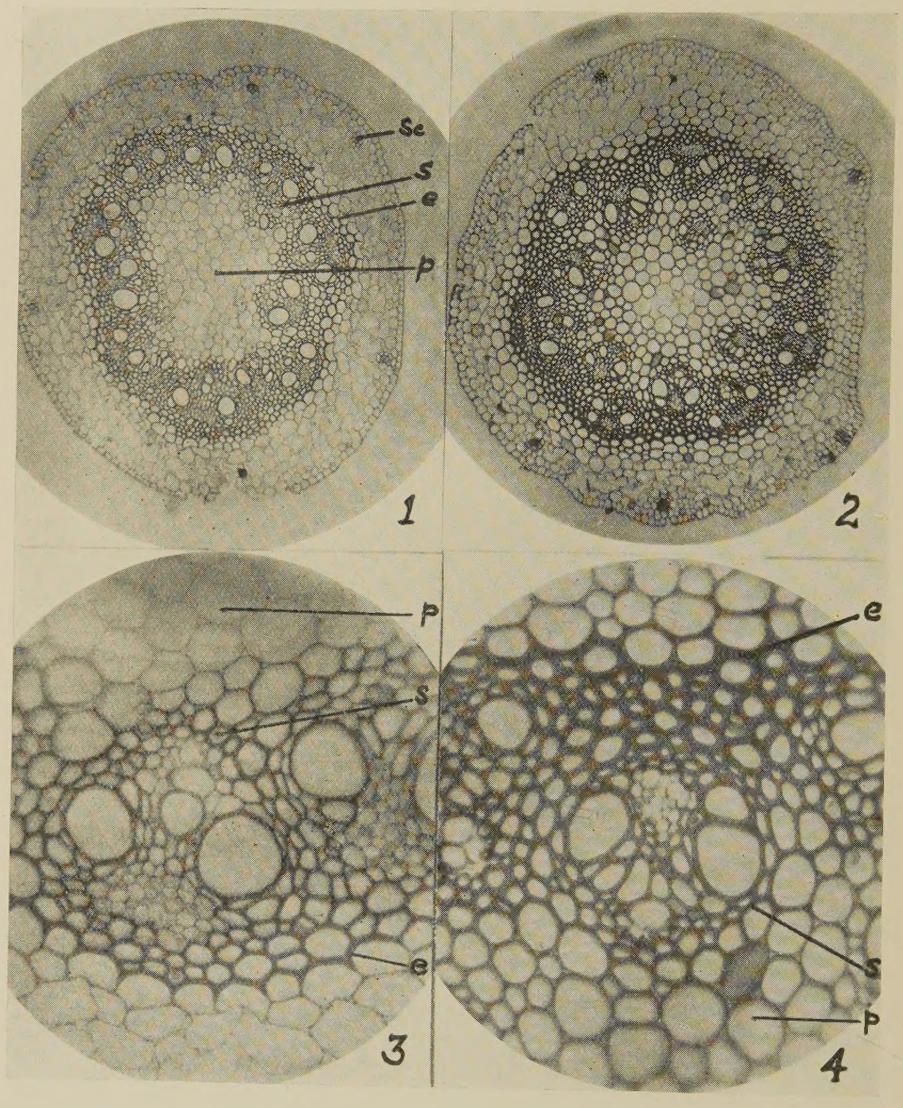

Plate II. Maturation of tissue in subcoronal-internode and crown.

1. Transverse section through the subcoronal internode of a non-inoculated check plant 20 days old, just below the crown, showing uniformly thickened endodermis (e), slightly thickened sheath fibres (s), thin-walled pith (p), and sclerenchyma groups (sc) in the cortex. There is little evidence of lignification. × 70.

2. Transverse section through the subcoronal internode of a non-inoculated check plant 110 days old, just below the crown, showing a marked increase in thickness of endodermis and sheath fibres. The sheath fibres and vessels are much lignified. × 70.

3 and 4. Higher magnification of a portion of the vascular cylinder of sections shown in figures 1 and 2 respectively. × 250.

Base of the Crown. The intricate manner in which the xylem elements branch off to the roots in this region makes it difficult to obtain comparable sections from different plants. Avery (*2*) says the vascular system of the primary root connects with the coleoptile, and Fellows (*5*) states that the first, second, and third leaves receive vascular traces from the sub-coronal internode, while the first pair of crown roots connect with the subcoronal internode only, the second pair with the internode and the fourth leaf, and the third pair with the leaves and culms only. This agrees with my observations.

Towards the crown the cortex of the roots and subcoronal internode becomes very narrow, while the sclerenchymatous tissue diminishes and then vanishes. In general the progress of lignification parallels that in the internode and crown roots. In plants over 50 days old only the bast and a small amount of parenchyma fail to show lignification.

Histology of Diseased Wheat Roots

The histology of wheat plants in the seedling stage infected with *Ophiobolus graminis* has been rather fully reported by Fellows (*5*), and also to a less extent by Davis (*4*) and others. The present report is based largely upon studies on plants in post-seedling stages. The observations which I made on plants in the seedling stage have been in almost complete agreement with those reported by Fellows for this stage. The phenomena associated with infection by O. graminis in the post-seedling stage, are, in general, very similar to those that occur in the seedling stage.

As pointed out by Fellows and others, the hyphae of *O. graminis* are of two kinds; macrohyphae, which are large in diameter, thick-walled, and dark; and microhyphae, which are smaller in diameter, thin-walled, and colourless. In one section the macrohyphae measured about four microns, and the microhyphae about one micron in diameter. The macrohyphae are found on the outer surface of the foot of the plant, in the outer cells of the cortex, and occasionally in the vessels, while the microhyphae are commonly observed deeper in the tissue.

No clear case of penetration from the outside was observed in older plants. These seem to have been infected early and the mycelium and softer tissue to have disintegrated to a considerable extent. Several instances were observed where infection of a crown root had apparently come through a root hair and invaded the adjacent cortex. In younger plants infection of the type described by Fellows has been observed often. Generally there is more or less massing of mycelium on the outside of the epidermis and penetration is accompanied by the protuberances on the inner wall which Fellows (*5*) has called "lignitubers" and Foex and Rosella (*7*) "reaction buttons" (Plate III. 2).

Seminal Roots. All tissues of the seminal roots seem to be penetrated with ease and are soon badly disintegrated. The epidermal and cortical cells around a young infection such as those shown in Plate III. 1 and 2, and Plate IV. 4, stain decidedly red with safranin and green with methyl green. It is observed that in many cases where badly in-

fested seminal root joins the scutellar node, the infection ends abruptly near the node, although no chemical or morphological change in the cell walls demonstrable by this method is apparent. Farther from the node the infection becomes deeper and deeper, and the growth of the hyphae seems to be chiefly in a radial direction, whereas nearer the node it is more in the direction parallel to the axis. This may be because the younger tissue farther from the node is more easily penetrated. In older roots, where the stele is lignified, the cortex is sometimes riddled and lignitubers present in the pericycle, but apparently no mycelium in the stele. Frequently in such cases many cells near the node are plugged with a dark staining material, mentioned earlier. Although the endodermis is much thickened at an early age, it is not lignified, and seems to offer little resistance to penetrating hyphae.

Lignitubers are abundant both on the end and side walls of epidermal and cortical cells, and on the outer cells of the stele. Although thousands of these have been observed so few have been found with a definitely continuous hyphal association that their connection with penetration was at one stage doubted. However, in a few cases there was undoubtedly a hypha emerging from the lignituber and in one face view slightly at an angle so there could be no doubt that a hypha had ruptured the apex of the lignituber. Again a macrohypha has been observed to enter a wall, where it appeared from a posterior view that an opening had been dissolved for it, but it was impossible to determine with certainty whether there was a lignituber on the other side in such cases. On the other hand, no certain case of emergence from a wall without a lignituber has been seen. However, microhyphae, at least, seem to be able to penetrate walls without lignitubers. Possible microhyphae, which had disintegrated, have been associated with some of the lignitubers where no hyphal connection was found.

Plate III. Phenomena associated with penetration by *O. graminis*.

1. Infection by *O. graminis* in the cortex of the scutellar node of a plant 20 days old, inoculated at seeding time. Lignitubers are prominent at (a). All cells shown take the lignin stains. × 550.

2. Penetration of the epidermis of the coleoptile of a plant 20 days old, near the scutellar node. Several hyphae (h) are seen outside and two lignitubers (l) within the cell. × 365.

3. Longitudinal section of a seminal root of the same plant showing lignitubers on an end wall (a), and several others in face view (b) × 365.

4. Mycelium and one lignituber (l) in the cortical cells of a plant 100 days old, inoculated at 40 days. × 525.

5. A branched lignituber (l) extending across a cortical cell of a crown root in the same plant. × 365.

6. Two branched lignitubers (l) in a longitudinal section of a plant 100 days old, inoculated at seeding time. × 365.

7. Section of a culm just off the crown in a plant 94 days old, inoculated at 50 days, showing characteristic plate mycelium (m) and parenchyma riddled by mycelium below. × 525.

8. Section from the culm of a plant 80 days old, inoculated at 50 days, showing parenchyma cells filled with mycelium, coloured matter and one lignituber (l). × 525.

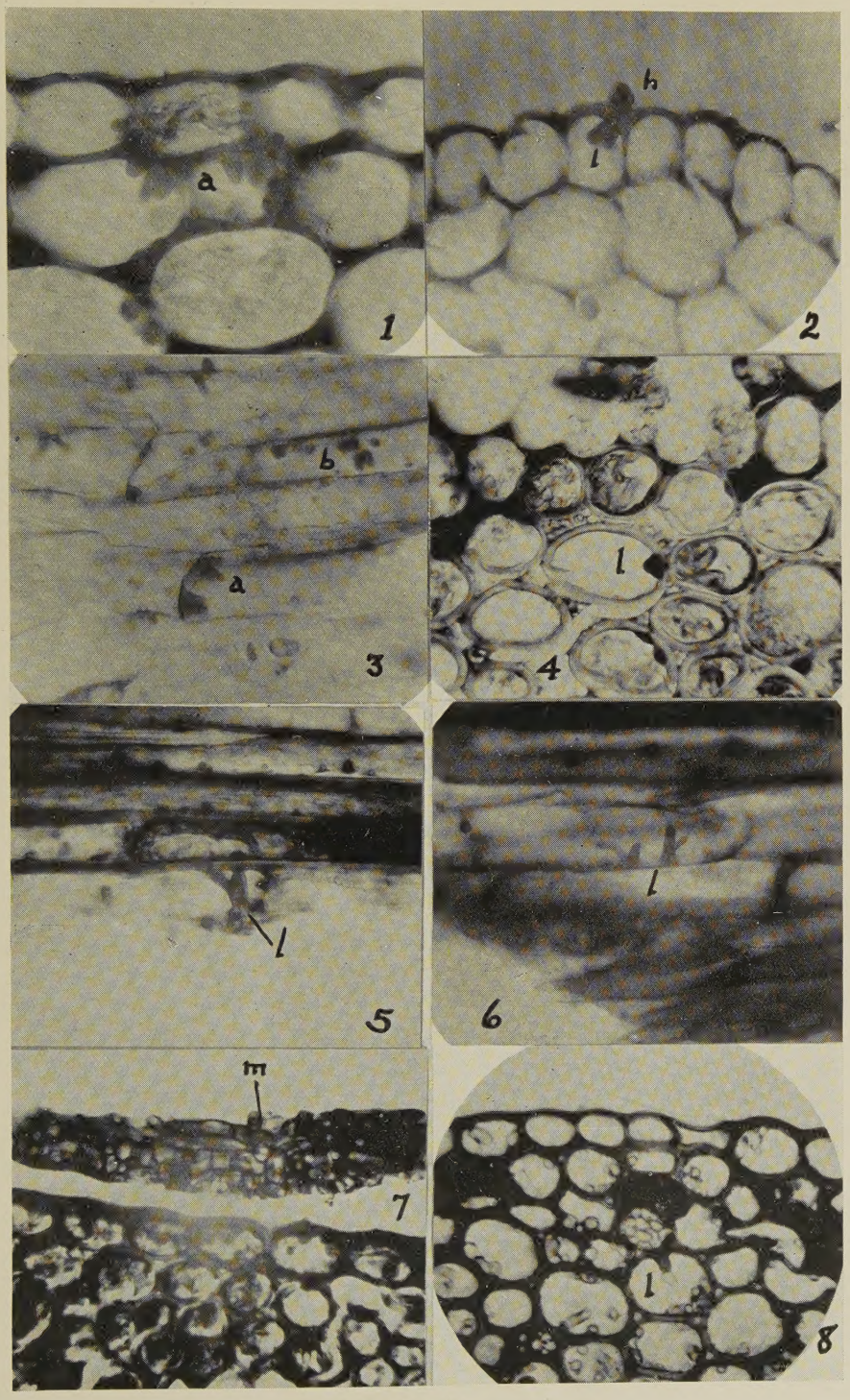

PLATE III. *See foot of opposite page.*

Although lignitubers are occasionally found on both sides of a cell wall, the vast majority of them occur on the inside only, and point in the general direction of progress of the infection. This would seem good evidence that lignitubers are associated with the penetrating hyphae.

Since the completion of this work, Kolk's (*9*) article on smut infection has come to hand, in which she infers that Fellows' "lignitubers" are nothing more than the cellulose sheaths surrounding mycelial strands described for smuts by Fischer von Waldheim (*6*), Lutman (*10*), and others, under a new name. The formation of these protuberances, as evidenced by the series of stages in development observed, seems to agree with Lutman's description of the cellulose sheaths, rather than with that of Kolk (*9*); that is, they appear to be successive thickenings of the host cell wall, rather than swellings of the penetrating hyphae. As the accompanying microphotographs show, they are definitely coneshaped with their bases continuous with the cell walls, and frequently branched or warty, as if emergence from them had been attempted in more than one place. Whatever their chemical constitution, they certainly have staining properties very similar to the normal thickenings of the known lignified elements and quite different from those of the known cellulose elements, even when appearing in the tissue where the walls normally have the characteristic cellulose staining properties.

Subcoronal Internode. Infection of the subcoronal internode appears to come through the epidermis in much the same manner as in the case of seminal roots (Plate IV. 3). The lighter infections are much more localized than in the roots, often the cortex being badly infested in one region, but the stele quite free from disease. Commonly the infection in the cortex ends abruptly near the crown. In one field of view may be seen cells tightly packed with mycelium and adjacent cells nearer the crown quite clean.

Crown Roots. Infection of the crown roots is very like that of the seminal roots. However, the extent and seriousness of the attack may be modified greatly, apparently depending on the maturity of the various tissues. Cases for observing this were obtained either by delaying inoculation of the soil (as explained earlier) or by examining cases where delayed

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Plate IV. Phenomena associated with penetration by *O. graminis*.

1. Section from adventitious root from a node about ¾ inch above the crown in a plant 110 days old, inoculated at seeding time. The thick-walled subepidermal cells are uniformly filled with dark mycelium, fine strands are seen to cross the cortex and enter the stele. × 75.

2. Section of a crown root just below the crown in a plant 50 days old, inoculated at seeding. Cells of the cortex are completely filled with mycelium. × 65.

3. Section from the subcoronal internode of a plant 100 days old, inoculated at 40 days. The infection is general and some tissue is disintegrated. × 125.

4. A young infection at the base of the coleoptile of a plant 20 days old, inoculated at seeding. The mycelium (m) has massed on the outside of the epidermis and lignitubers are abundant. The walls nearby took the lignin stains. × 365.

5 and 6. Sections from the culm of a plant 80 days old, inoculated at 50 days, showing coloured matter and hyphae in a vessel (v) and coloured matter in parenchyma cells. × 525.

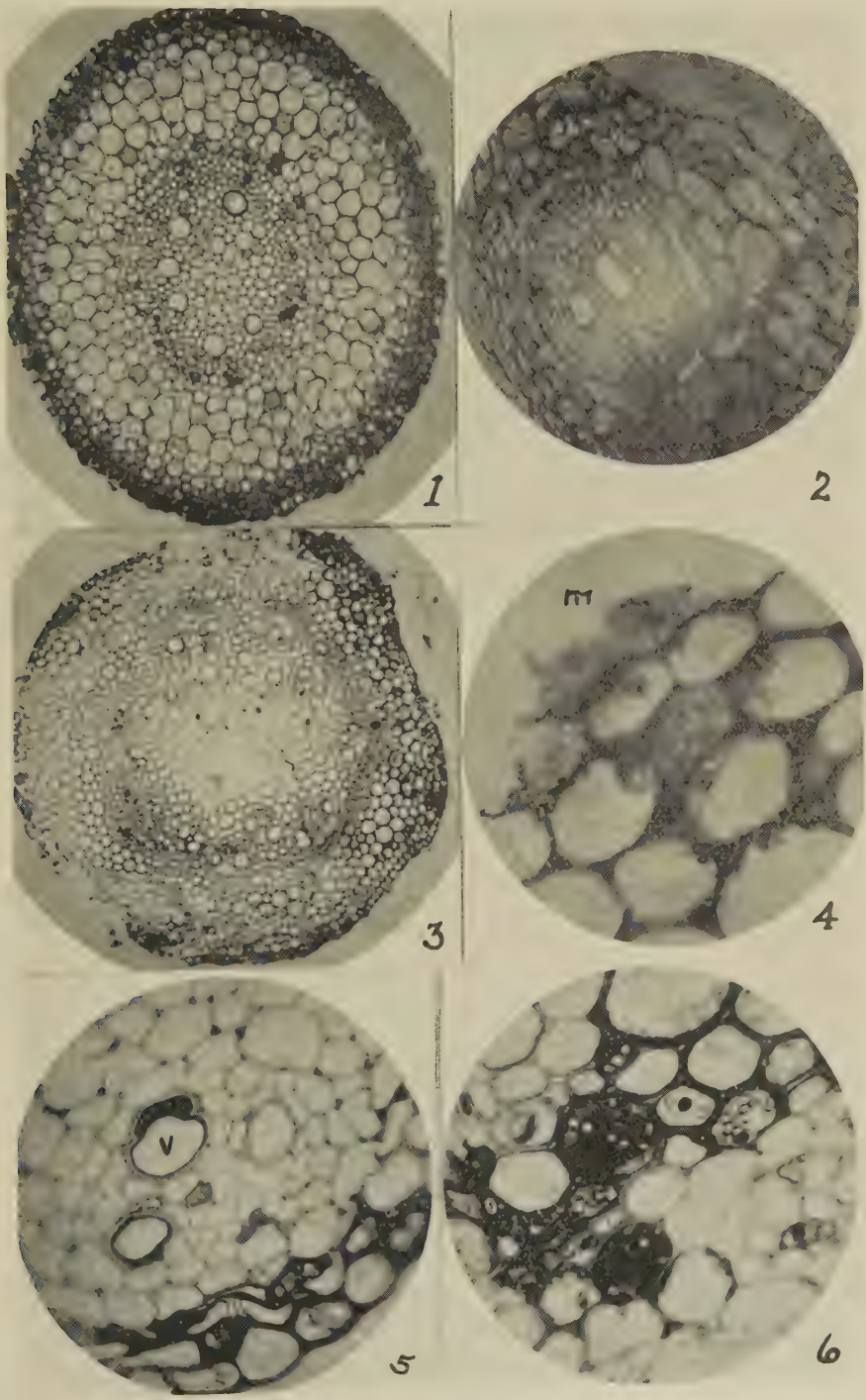

PLATE IV. *See foot of opposite page.*

infection apparently had occurred naturally. One may find the cortex uniformly invaded, and the cortex, pith and bast much disintegrated, but the stele extensively lignified and relatively intact, with perhaps some microhyphae. On the other hand, cases arise where the infection does not get beyond the subepidermal layer, although incipient penetration of the root occurs in several places. In the former case it is assumed that extensive penetration took place prior to lignification of the subepidermal sclerenchyma layer but not before the stele became sufficiently lignified to greatly impede further progress of the pathogene. In the latter case it would appear that a delay in infection of the roots permitted sufficient thickening of the subepidermal sclerenchyma layer in the tissue to arrest deeper penetration.

Even when all tissues are invaded, usually the hyphae are massed in the thick-walled subepidermal cells and the growth there is largely parallel to the axis. Lignitubers are especially abundant in this tissue. Sometimes the fungus gets no further, and sometimes fine strands cross the thin-walled cells of the cortex and mass again in the cells next to the endodermis, and in the pericycle and tracheids, if it reaches that depth.

Crown. Entrance to the crown always seems to take place through the subcoronal internode and particularly the crown roots. In the majority of plants studied, even though these were badly diseased, the crown was clean, or only the cortex, or a small portion of the other tissue diseased. Of course the plants all survived, although injured to varying degrees, and it is assumed that if the crown had become infested with the fungus early enough the plant would have succumbed. It seems probable that if the fungus reaches the crown early enough it penetrates it easily, but if the crown is sufficiently matured when the fungus reaches it, penetration is slower and more difficult. Perhaps this fact would help to explain much of the diversity in root rot injury observed under field conditions, with special reference to degree of bleaching of the spikes and culms and to shrinkage of the grains.

Many vessels in the crown are plugged with a fairly homogeneous dark matrix (Plate IV. 5, 6). Sometimes hyphae can be seen in this matrix, and often no myclium is apparent in any cell in the vicinity. Although similar dark cells are sometimes found in non-infected check plants, and also in cortical cells of diseased roots, they are much more frequent in the crown region of diseased plants. Fellows (*5*) thinks this condition is due to a thickening of the cell wall, sometimes in advance of the fungus, to cut off its progress. The nature of the pigmentation of the matrix suggests that an enzyme from the fungus may be responsible for the coloration at least. It is also possible that there are two types of plugging, since in some cases the matrix is very dark, while in other cases it is lighter in colour and takes the lignin stain. Sometimes the matrix has a granular appearance, but this is usually associated with advanced degeneration.

In one plant 80 days old, inoculated at seeding time, the seminal roots were severely diseased. The scutellar node was clean but some cells were plugged. Six crown roots examined were all diseased and the

cortex considerably disintegrated. The steles of three of them were only slightly invaded. The younger roots were much more diseased than the older ones, which is taken to indicate that the older ones were lignified to a greater extent when the fungus attacked them. The root most damaged showed little evidence of lignification and was probably attacked before lignification set in. The fungus in all of the roots rapidly diminished as the crown was approached and plugging was pronounced in all cases. Mycelium was not observed in the xylem of the crown. It may be added that the height of this plant was 96 cm., while that of the check plant was 97 cm. Also that it produced four fertile culms out of six, and on external appearance of the foot it was given a disease infection rating of 90 per cent.

Plants inoculated at later dates differed from those inoculated at seeding time only in being attacked to a very much less extent. The older they were when inoculated, the less evidence there was of infection, and there seemed to be a marked decrease after 40 or 50 days, which corresponds fairly well with the progress of maturation in the root. However, environmental factors, such as moisture, no doubt influence this considerably, both by affecting the growth of the fungus and by preventing the early maturation of the plant tissues.

It has been commonly observed in the field that the lateral shoots are more severely damaged than the ones which develop earlier. This applies particularly to the first lateral shoot, which has its origin in the axil of the coleoptile (Figure 1, s). A possible explanation is that the fungus has permeated the soil around the plant before the secondary roots from these shoots were matured enough to offer much resistance to it, but not before the older roots were matured to that extent.

Culm. The characteristic plate mycelium commonly associated with *O. graminis* is often found at the base of the culm (Plate III. 7). No definite case of penetration of the epidermis of the culm from this plate mycelium was found in any of the material examined. However, cases were observed where the epidermis and a layer of tissue, a few cells deep, below it were disintegrated and lignitubers were sometimes present on the outer wall of the epidermis next to the plate mycelium. The diseased lesions seemed to be more localized in the culms than in the roots. Often in the former case the cortical cells and occasionally the xylem vessels were completely packed with macrohyphae, while other cells were plugged with a black-pigmented substance (Plate III. 8).

In new penetrations of the coleoptile, the parenchyma around the point of penetration takes the lignin stains, but no increase in thickness of the walls is noted. This stain reaction has not been observed to accompany penetration in the roots.

It seems that maturation of the above-ground nodes of the culm takes place more rapidly than in the foot of the plant. The xylem of the coleoptile and the first node above the crown appears to be well lignified in young plants before the roots, subcoronal internode or crown show any evidence of lignification. This rapid maturation may offer some explanation of the localization of infections in these regions.

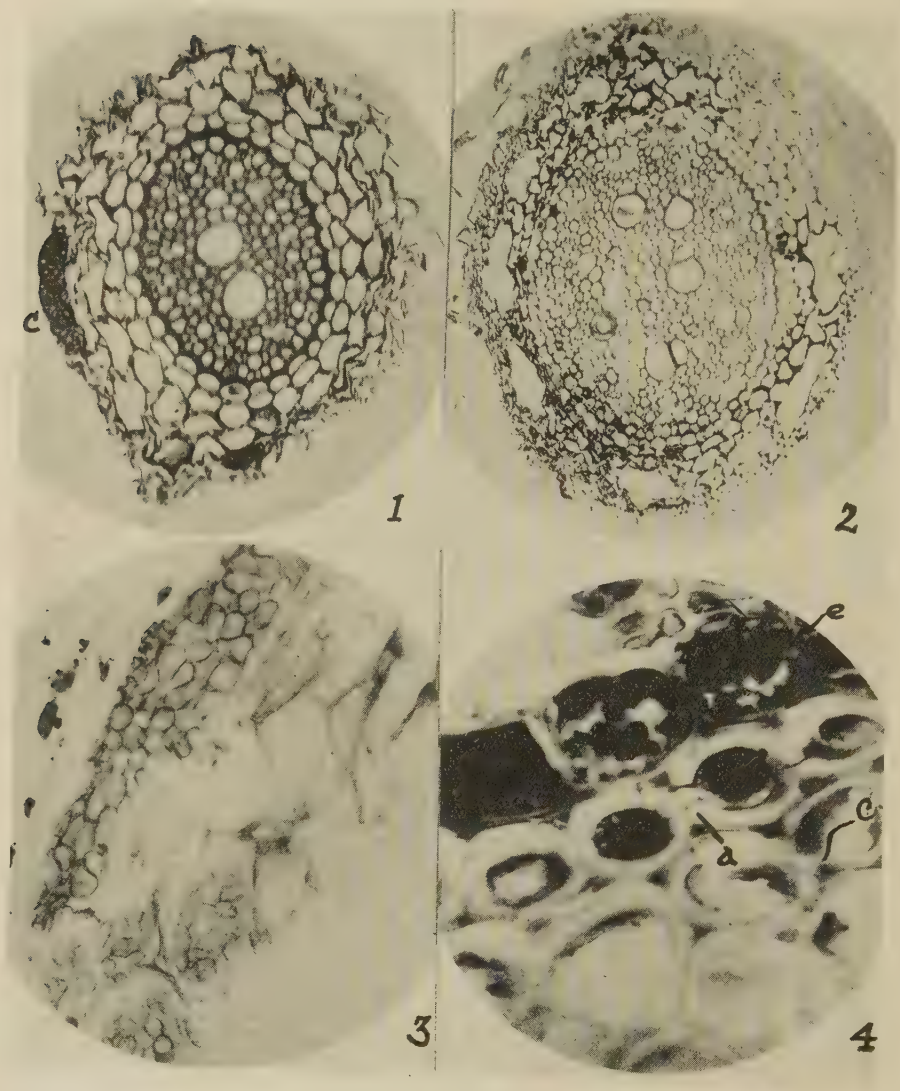

Plate V. Further observations on penetration by *H. sativum, Fusarium* sp. and *O. graminis.*

1. Section from a seminal root of a plant 40 days old, inoculated with *Helminthosporium sativum* at seeding. The cortex is somewhat disintegrated, but no mycelium is apparent. Peculiar isolated cells in the cortex (c) are tightly packed with dark mycelium. × 175.

2. Section from a crown root of a plant 50 days old,inoculated with a mixture of *O. graminis, H. sativum* and *Fusarium* sp. at seeding. The cortex is disintegrated and there is mycelium in the stele. × 140.

3. Section from a diseased plant collected from field, showing densely packed cells. No other mycellium is evident. × 350.

4. Section from another plant collected from field, showing epidermal cells (e), and cortical cells (c) of a crown root filled with disintegrated mycelium and coloured matter, which extends through the pits at (a). × 750.

Discussion

The appearance of the roots of plants inoculated in pot culture with a mixture of *Ophiobolus, Fusarium* and *Helminthosporium* is much the same as those inoculated with *Ophiobolus* alone (Plate V. 2). The stele is penetrated, the cortex disintegrated, and what mycelium remains seems to be of the *O. graminis* type. Indications are that possibly the others had entered, but that their mycelia disintegrated before that of *O. graminis*, thus concealing their identity and effect.

The only morphological character found which could be used to distinguish *O. graminis* infection from that of *H. sativum* or *Fusarium sp.* in post seedling wheat plants is the protuberances referred to as lignitubers. The presence of these seems to be fairly constant, particularly in the sub-epidermal layers of the cortex of secondary roots, and they seem to persist along with the walls even though the mycelium has disintegrated. Somewhat similar structures have been reported in plants attacked by other pathogens, but judging from the illustrations accompanying the descriptions of these, they could be distinguished from lignitubers with a fair degree of certainty. Apparently neither *Fusarium* sp. nor *H. sativum* produce lignitubers or comparable structures, at least none were found in the specimens examined, and, judging from the literature, they have not been observed by others. On the other hand, tissue invaded by microhyphae of *O. graminis* does not differ perceptibly in appearance from that invaded by the other two pathogens, and lignitubers may not be present. However, no instance is recalled where microhyphae were present in a root and macrohyphae were not found in the outer tissue of the same root.

This does not, of course, preclude the possibility of the other fungi also having been present, but where *O. graminis* is present, it is a fairly reasonable conclusion that it is the pathogene primarily concerned, because of its known virulence and apparent lack of ability to play a secondary rôle as a place saprophyte, which rôle the root-rotting strains of *H. sativum* and *Fusarium* sp. do well.

The black mycelial plate of the culm, the shiny black subcoronal internode, and the blackened seminal and secondary roots are all fairly reliable external indications of attack by *O. graminis*. However, these so-called "typical symptoms" apparently do not always appear under field conditions. In dry soils the tissue is not blackened to the usual extent, but has a brown appearance more typical of the *Fusarium* and *Helminthosporium* root rots, thus making it impossible to decide, on a colour basis alone, which of the pathogens are concerned.

Further, while discoloration of the foot usually has been found to be associated with infection by root-rotting fungi, it is not always so, for the specimens which were examined in this study indicate clearly that discoloration may also be associated with drought. In the case of drought discoloration is more confined to the walls of the cells, and fungous mycelium may be absent.

It is well known that some suscepts show increased resistance towards certain pathogenes with advancing age, others less, and that morpho-

logical and physiological types of resistance are involved singly or in combination, depending on the suscept. Whether or not the typical take-all patches occurring in field culture, in which the plants are progressively stunted towards the centre, can be wholly explained on the basis of the increased lignification of the tissue associated with advancing age, there would at least seem a possible explanation from this angle. If in the centre of such patch, the inoculum is most abundant or most virulent, these plants would naturally be attacked first and most severely. However, under field conditions in Alberta it is commonly observed that plants do not show signs of attack by *O. graminis* until after the seedling stage. Whether this means that the amount of inoculum is not sufficiently increased to be effective until later in the season under our conditions is still a question. However, if the inoculum tends to spread from the initial centre of the typical take-all patch, which it probably does, to infect the neighbouring plants, this progress would synchronize with the gradually increasing resistance supplied by the increase of lignification in the tissues, with the result that taller plants farther away tend to escape, being more lignified. It is at least reasonable to expect that this factor plays a rôle in producing the typical take-all patches, as it would also in cases where one or more plants are more severely attacked here and there throughout the field.

Naturally the ability of plants to continue to produce new secondary roots as others are disabled by attack is a most important factor in keeping the suscept alive. It is well known that a vigorous wheat plant has an amazing ability to produce a succession of secondary roots. When this ability is lost through destruction of the crown itself, or by the more or less complete attack of new crown roots, the injury is severe, and the damage, as reflected in yield of grain, might be increased by environmental factors such as drought and high temperatures. The extent of injury to the plant seems to depend upon the age of the tissue when the pathogene gains entrance. Apparently there are at least two important protective factors, viz. lignification and the production of secondary roots, and as these factors are not fully felt in pot culture until the plant nears the 40-day-old period, the plant is more easily attacked before this stage. At least this study would indicate that this conclusion is well founded. Whether other chemical changes which may occur in the tissue with increasing age augment the susceptibility or the resistance to root-rotting fungi, and how external factors such as food, temperature and light affect these, remain to be investigated.

Summary

The morphological changes associated with the aging of the tissue in the foot of Marquis wheat plants and penetration by *O. graminis*, *H. sativum* and *Fusarium* sp. have been examined, with particular reference to *O. graminis*.

A marked increase in the amount of lignified tissue in the foot of Marquis wheat plants takes place with advancing age. This has reached its maximum by about 40 days in pot culture. The increase in lignification occurs chiefly in the xylem, the pericycle, the fibres of the vascular bundle

sheaths, and in the subepidermal layers of the cortex of the crown roots. The cells of the latter become much thickened with advancing age.

The increase in lignification observed is coincident with a marked falling off in infection of wheat plants by *O. graminis* after 40 days, under greenhouse conditions. It is thought that the thickening of the walls and the increase in lignification or other chemical changes accompanying maturation of the root at times may prevent further progress of the root-rotting fungi.

Infection and penetration phenomena in post-seedling plants are essentially the same as in the seedling stage. All tissues of the seminal roots may be penetrated with ease when young, as can also the young tissues of the secondary roots. Penetration of the crown invariably seems to come from the subcoronal internode and particularly from the crown roots. Evidence is that extensive penetration of tissue usually occurs before marked lignification has taken place, and that the advance is progressively slower as the crown is approached, both in crown roots and in the subcoronal internode. Lighter infections appear to be more localized in culm and subcoronal internode tissues than in primary or crown roots.

"Lignitubers" are commonly associated with penetration by *O. graminis*. Similar structures apparently do not occur with *H. sativum* or *Fusarium* sp. Lignitubers react positively to the lignin stains, are often branched, usually point in direction of penetration, hyphae may emerge from the protuberances, and, finally, they are considered to be a lignin-like growth-reaction of the cell wall in response to penetration or attempted penetration by macrohyphae.

Discoloration of the foot is usually, although not always, associated with infection and the presence of mycelium.

Severe drought may also discolor the tissue, in which case discoloration is confined more to the cell walls.

Cases often arise where the mycelium has disintegrated following invasion, leaving dark substances which collect in the cells.

While *O. graminis* may usually be identified by histological means, it does not seem possible to distinguish accurately all cases of root rot caused by *O. graminis* from those caused by *H. sativum* or *Fusarium* sp. by the technique used.

Acknowledgment

Acknowledgment is gratefully made to Dr. G. B. Sanford for suggesting the problem, and criticizing and revising the manuscript. Also to Mr. W. C. Broadfoot for assistance and valuable advice while the work was in progress.

REFERENCES

1. Athanasoff, Athanas, D. L'anatomie et la maturation des chaumes d'un pied de Blé Colosse de Razgrad (*Triticum turgidum* L.) avec un résumé en Espéranto. Thèses présentées a la Faculté des Sciences de Paris. 96 pp. 1928.

2. Avery, George S. Jr. Comparative anatomy and morphology of embryos and seedlings of maize, oats and wheat. Bot. Gaz. *89*: 1-39, 1930.

3. Broadfoot, W. C. Does the wheat plant become more susceptible to the foot rotting fungi with increasing age? Ann. Rept. Dominion Botanist, 1930. Dept. of Agric. Canada.

4. Davis, Roy J. Studies on *Ophiobolus graminis* and the take-all disease of wheat. J.A.R. *31*: 801-825. 1925.

5. Fellows, Hurley. Some chemical and morphological phenomena attending infection of the wheat plant by *Ophiobolus graminis*. J.A.R. *37*: 647-661, 1928.

6. Fischer Von Waldheim, A. Beiträge zur Biologie und Entwickelunsgeschichte der Ustilagineen. Jahrb. Wiss. Bot. *7*: 61-144.

7. Foex, E. and Rosella. Recherches sur le pietin. Annales des Epiphytes *16*: 51-82, Mars et Avril, 1930.

8. Kirby, R. S. The take-all diseases of cereals and grasses caused by *Ophiobolus cariceti* (Berkeley and Broome) Saccardo. Cornell Univ. Agric. Exp. Sta. Memo. 88: 45 pp. 1925.

9. Kolk, Laura A. Relation of host and pathogen in the oat smut, *Ustilago avenae*. Bull. Torrey Botanical Club *57*: 443-508, 1930.

10. Lutman, B. F. Some contributions to the life history and cytology of the smuts. Trans. Wisconsin Acad. Sci. *16*: 1191-1228, 1910.

11. Percival, J. The wheat plant. Duckworth & Co., London. 463 pp. 1921.

12. Sanford, G. B., and Broadfoot, W. C. Studies of the effects of other soil-inhabiting micro-organisms on the virulence of *Ophiobolus graminis* Sacc. Sci. Agr. *11*: 512-528, 1931.

13. Simmonds, P. M. and Sallans, B. J. Root amputations in the study of root-rots of cereals. Proc. Can. Phytopath. Soc. 33-43, 1930.

14. Weaver, J. E. Root development of field crops. McGraw-Hill, New York. 291 pp. 1926.

A STUDY OF VARIOUS FACTORS INFLUENCING SEED PRODUCTION IN ALFALFA (*MEDICAGO SATIVA*)[1]

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Introduction

Alfalfa is recognized as a crop which exhibits wide seasonal differences with respect to yield of seed. Failures in the seed crop are frequent and often it is difficult or impossible to assign specific cause. This problem has occupied the minds of many workers in agronomy. Climatic factors have been considered as most important but it would appear from a review of the literature that there are other factors as well which influence seed setting. These include genetic differences and peculiarities of the flower which have to do with fertilization.

In the investigation the writer has confined her attention almost entirely to a study of agencies which affect the "tripping" of alfalfa flowers, characteristics of alfalfa pollen, and climatic factors in relation to seed production. Attention has been directed especially to climatic conditions as they affect seed production in Peel County, Ontario, a district in which the alfalfa seed crop is of considerable economic importance.

Importance of Tripping

Earlier writers, on the whole agree that tripping is necessary for the production of an appreciable amount of alfalfa seed, but in later years some writers have brought forth conclusions which support the idea that fertilization of alfalfa flowers takes place to a large extent without tripping, at least in certain regions. Westgate (*37*), Torssell (*32*), Helmbold (*16*), Coffman (*10*), J. H. Lovell (*18*), and J. W. Carlson (*6*) have all discussed this problem. The writer found that alfalfa flowers carefully handled and examined in the field practically always showed the anthers dehiscing and the stigma covered or partly covered by the pollen. Tripping did not give increase in seed production as compared with natural development at the Ontario Agricultural College, according to data obtained by Dr. McConkey. Tripping was found to increase seed production according to Piper (*25*), Frandsen (*12*), Southworth (*29*), Hay (*15*) and Clarke and Fryer (*9*) as compared with natural development of enclosed flowers.

Agents of Tripping

Influence of Direct Heat

Piper (*25*) mentions automatic tripping as accomplished by heat from the sun. He accomplished tripping by using a burning glass. The writer brought about tripping by using the sun's rays focussed on a certain point of the keel through a burning glass. This point is located a little below the middle of the hood of the keel on the inside suture. Tripping was also ac-

[1]Abstract of a thesis submitted to the graduate school of the University of Toronto. The work was done in the Department of Field Husbandry, Ontario Agricultural College, Guelph, under the direction of Prof. W. J. Squirrell.

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complished by applying direct heat from a lighted match or an electric light to a piece of glass on which the alfalfa flowers rested.

Influence of Insects

Honey bees are no longer thought to be of importance in the tripping of alfalfa. Bumblebees and Megachile sp. and Andrena sp. are the most important insects for tripping on this continent. Brand and Westgate (*3*), L. A. Aicher (*1*), T. W. Sladen (*28*), and J. H. Lovell (*18*) have written on this subject. In Europe Torssell (*32*) and Helmbold (*16*) have written about insects being of importance for tripping of alfalfa. The writer caught specimens of *Andrena Wilkella,* Kirby and *Andrena* (*Trachandrena*) *crataegi,* Robertson. The first of these was found to trip the flowers and the second also tripped the flowers and thereafter gathered the pollen. Of sweat-bees, specimens of *Halictus* (*Chloralictus*) *albipennis,* Robertson and *Halictus provancheri* Dalla Torre were found. The first was found gathering pollen from tripped flowers; the second tripped the flowers and thereafter gathered the pollen.

Alfalfa Pollen and Its Functions in Relation to Seed Production

Torssell (*32*) emphasizes the importance of amount of pollen produced by individual plants with regard to seed production. He found that the pollen production decreases with inbreeding. Helmbold (*16*) also mentions the importance of selecting good pollen producers in alfalfa plant breeding work. Torssell, furthermore, carried out experiments to test the water-resistance of pollen. He found that strains with the highest water-resistant pollen also had the highest seed production in wet years.

Clarke and Fryer (*9*) found varying amounts of sterile pollen in anthers from different plants of Grimm Alfalfa. A group of plants which set practically no seed under field conditions, had high percentages of sterile pollen ranging from 50 to 90 per cent. It was also found that the percentage of sterile pollen, although varying between plants, remained constant for individual plants, even when the pollen was produced under different conditions.

The writer made analyses for sterile pollen in eight plants, as recorded in table 1. A percentage of 22.5 of sterile pollen does not seem to be of so much importance when the total amount of pollen is abundant. In spite of the small number of plants used, it is clear that the amount of pollen and its relative sterility exercises an influence over the individual plants, and is at least partly responsible for differences in seed production. The plant 1.j.1. was practically sterile, as it was found to produce only six fertile pollen grains of the small total of fifteen pollen grains which were found.

According to the records of selected plants which were planted in the nursery in 1926, several plants had not produced seed when selected. Among these was 1.j.1., which is included in the table. From seven others, a small number of flowers were taken and the anthers examined. Three of the plants had absolutely sterile anthers, three produced very little pollen and one flower produced an appreciable amount of pollen of which

about half was sterile. It was noted that very little tripping occurred on the plants, none of which produced pollen. As if warned by instinct or previous experience, pollen gathering bees were not observed visiting them. Plants which prove to have absolutely sterile anthers are of course eliminated from reproduction unless cross-pollination is successful.

Three of the plants which were examined for sterility were cross-pollinated with pollen from two good pollen producers and seed setters. The two of these plants which had large percentages of sterile pollen set pods when cross-pollinated, but the third, 1.j.1., which was practically sterile with regard to pollen, did not set a pod, in spite of crossing with good pollen. The question of ovule sterility rises here and must be considered. This plant was healthy and vigorous of growth, but scanty flowering.

A careful investigation of pollen sterility should have been carried out with material from farmers' fields to determine how large a role this phenomenon plays in the average plant population of alfalfa fields maintained for commercial seed production. The writer regrets that this was not possible in the time set aside for this work.

Germination of Pollen

No doubt Martin's (*21*) research regarding "Relations of moisture to seed production in alfalfa" is, at present, one of the most important works for the student of seed production in alfalfa. He made extensive germination experiments and found that:

"1. The setting of seed pods in alfalfa (*Medicago sativa*) is dependent upon the proper functioning of the pollen.

2. Germination of the pollen depends upon a proper supply of moisture. If the water supply is either above or below a certain requirement, the pollen does not germinate.

3. The water requirements for germination of the pollen depend upon a certain ratio between the moisture delivered by the stigma and the moisture of the air surrounding the stigma.

4. It follows, therefore, that when the optimum supply of soil and atmospheric moisture for pollen germination is available, an increase in soil moisture resulting in an increased moisture delivery of the stigma or a change in atmospheric moisture, disturbs the required moisture supply for pollen germination and prevents fertilization.

5. Blasting of the seed is due to arrested development of the embryo.

6. This arrestment may be due to the plant's inability to furnish the proper water and food supply for the maturing of seed during drought, or it may be due to the pathological conditions to which the seed is more susceptible under drought conditions."

Martin found, also, that different pollen grains require different moisture conditions.

The writer carried out a number of tests to determine whether there was a significant difference in the "germination power" of pollen from different plants and a possible correlation with seed production. Flowers from seven plants were used, an equal number from each plant. The

germination tests were carried out by placing the flowers in small glass phials, and providing different moistures inside these by applications of different amounts of water to a standard sized piece of cotton wadding. The temperatures under which these experiments were carried out ranged from 70° to 85° F.

Plant	Total Number of Germinated Pollen Grains	Seed production in Grams of Plants Used in Germination Tests		
		1929	1930	1931
1.g.1.	2840	20.0	19.1	Selfed 0.5
2.m.20.	700	So little seed not harvested.	8.4	Selfed 0.0
1.b.10.	985	Not selected	Not selected	5.3
1.d.4.	549	3.8	So little seed not harvested	Selfed 0.15
1.h.2.	801	5.7	Not selected	2.5
1.b.16.	422	Very little seed, not harvested	9.8	0.7
3.f.7.	691	2.4	8.4	1.1

In consideration of the small amount of manipulation (i.e. gentle rolling of the flowers between fingers) to which the flowers on the plants that were screened and selfed were exposed, the one-half gram of seed produced by 1.g.1. is a very good performance and indicates that this plant may prove very self-fertile in another year when more selfing can be done. The shading of the netting and the weak radiation from the sun to which the plant was exposed may partly account for the fact that spontaneous self-fertilization did not occur to a greater extent.

There is a strong indication that part of the superior seed producing ability of 1.g.1. rests with the vigorous germination of its pollen over a wide range of conditions, and its fast germination which enables it to make use of any favourable conditions even if these are of short duration. More work is necessary to confirm this.

General Climatic Conditions in Relation to Seed Production in Alfalfa, and the Main Causes of Fluctuations in Seed Yield.

All writers agree that climate in general is the limiting factor for seed production. Alter's (*2*) statement may be regarded as representative of the general opinion. He writes, "Climate is generally acknowledged to be the limiting factor in alfalfa seed production and the current weather the major factor affecting the annual yields."

Westgate (*37*) mentions the four factors which he considers most important in alfalfa seed production.

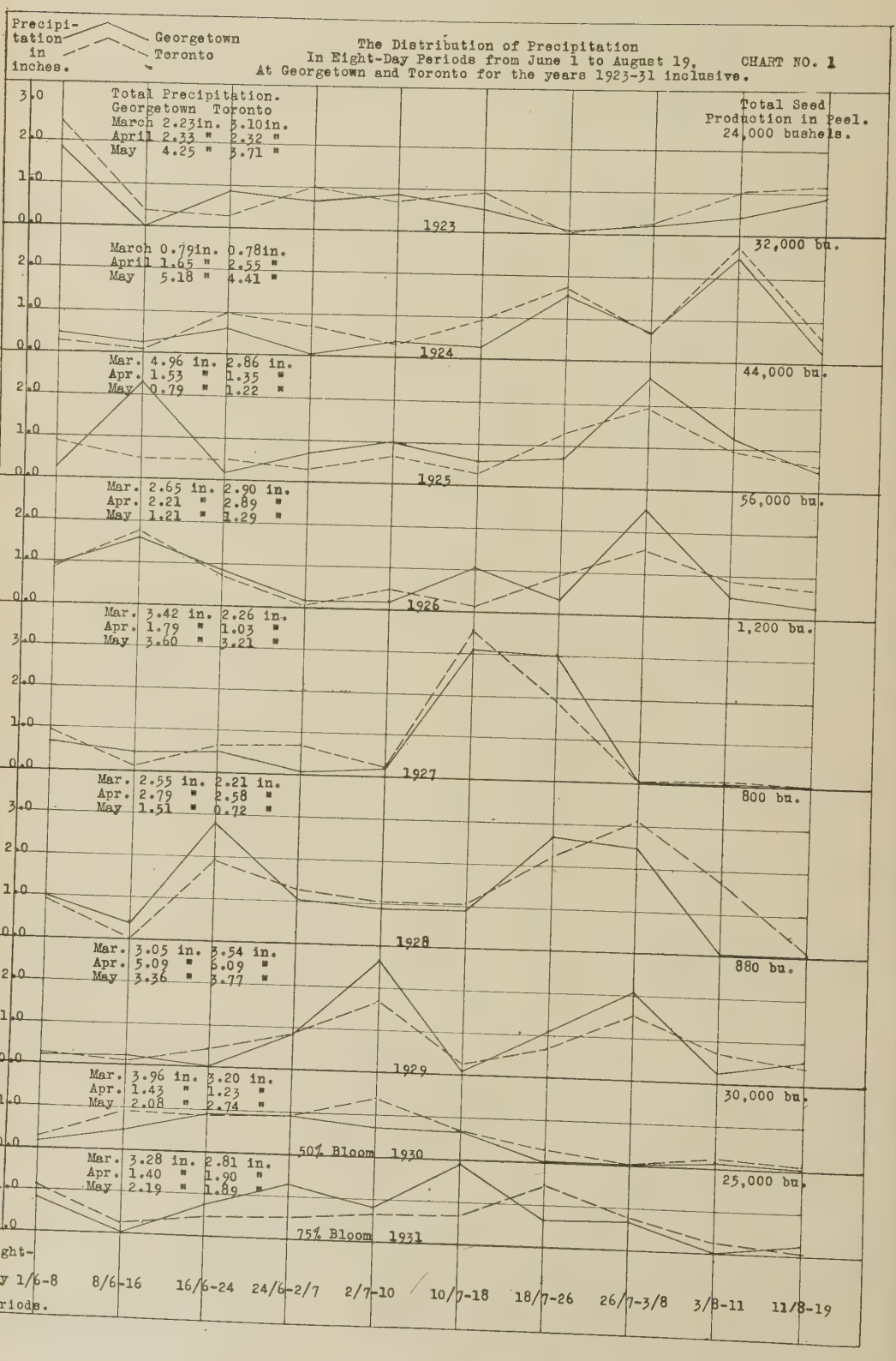
1. Thickness of stand.
2. Soil-moisture.
3. Rainfall.
4. Temperature.

Westgate (*37*), Blinn (*4* and *5*), Alter (*2*), Aicher (*1*), Brand and Westgate (*3*), Shoesmidth (*27*), Helmbold (*16*), Torssell (*32*), Spafford (*30*), and many others have emphasized these factors as important for the seed production of alfalfa.

Westgate recommends the thin stand, as it causes better development of the single plant and allows the individual plants to receive more sunlight. Martin (*21*) writes, "The humid air around crowded plants cuts down their transpiration, and by permitting the cells to retain more water may increase the water delivery of the stigma." This, of course, would tend to disturb the required moisture supply for pollen germination and prevent fertilization after the results of Martin's researches which were quoted previously in this paper. The writer's observations in Peel County also pointed to the importance of thin stands. The thin stands were always the best set with brown well-developed pods, and the highest seed yields were only obtained from fields with thin stands. The poorest yields were obtained from fields with crowded stands. Westgate (*37*) writes, "Soil-moisture must be sufficient to enable the plant to mature its seed crop and yet not enough to induce starting of the crown shoots in advance of the maturation of the seed crop, as the setting of seed is often greatly lessened when growth of the succeeding crop of stems begins. The margin between too much and too little water is a very narrow one, and it is owing more to this fact, than any other that alfalfa seed production is often so uncertain." Blinn (*4*) writes that without sufficient moisture the seed will "blast" and fail to fill.

In Peel County, in the district near East Caledon, there is a farm where alfalfa grows well but does not set seed to an extent that would make it worth while letting a crop stand for seed. In general, fertilization takes place and green pods form, but long before maturity most of them fall off. This year, a small piece of the field was let stand for seed, just to provide material for investigation. To a fair extent pods were formed and developed to maturity, but when they were threshed out the seed production proved to be very poor. Eighty-eight per cent of the seed were dead brown seeds, or "blasted" seeds as they are commonly called. The soil on this land is more sandy than the soil from the good seed producing areas and is less fertile. But due to the large amount of "blasted" seeds, the writer thinks that the limiting factor here is the texture of the soil which allows the soil moisture to escape quickly and thus prevents the plants from getting enough moisture at the time when the seeds should develop.

Summing up in general, from various writers' statements it may be said that before the blooming period there must be sufficient moisture for vigorous growth of the alfalfa plants. Near and during the first part of the blooming period, a dry spell sufficient to put the necessary "strain" on the plant to induce seed setting, is needed; during the rest of the blooming period light showers now and again are beneficial, as a certain amount of moisture is needed for fertilization. When the young pods are formed, heavier rains are favourable to provide the moisture necessary for the filling of the pods. Stripping of the flowers in the blooming period is due to failure of fertilization, and can be caused by extreme moisture, or extreme heat with frequent high, dry winds.


Precipitation in inches.
Georgetown
Toronto
The Distribution of Precipitation
In Eight-Day Periods from June 1 to August 19, At Georgetown and Toronto for the years 1923-31 inclusive.
CHART NO. 1
Total Precipitation.
Georgetown Toronto
March 2.23in. 3.10in.
April 2.33 " 2.32 "
May 4.25 " 3.71 "
1923
Total Seed Production in Peel.
24,000 bushels.
March 0.79in. 0.78in.
April 1.65 " 2.55 "
May 5.18 " 4.41 "
1924
32,000 bu.
Mar. 4.96 in. 2.86 in.
Apr. 1.53 " 1.35 "
May 0.79 " 1.22 "
1925
44,000 bu.
Mar. 2.65 in. 2.90 in.
Apr. 2.21 " 2.89 "
May 1.21 " 1.29 "
1926
56,000 bu.
Mar. 3.42 in. 2.26 in.
Apr. 1.79 " 1.03 "
May 3.60 " 3.21 "
1927
1,200 bu.
Mar. 2.55 in. 2.21 in.
Apr. 2.79 " 2.58 "
May 1.51 " 0.72 "
1928
800 bu.
Mar. 3.05 in. 3.54 in.
Apr. 5.09 " 6.09 "
May 3.36 " 3.77 "
1929
880 bu.
Mar. 3.96 in. 3.20 in.
Apr. 1.43 " 1.23 "
May 2.08 " 2.74 "
50% Bloom 1930
30,000 bu.
Mar. 3.28 in. 2.81 in.
Apr. 1.40 " 1.90 "
May 2.19 " 1.89 "
75% Bloom 1931
25,000 bu.
Eight-day periods.
1/6-8
8/6-16
16/6-24
24/6-2/7
2/7-10
10/7-18
18/7-26
26/7-3/8
3/8-11
11/8-19

Influence of the Summer Precipitation on the Alfalfa Seed Production in Peel County, Ontario, and at the Ontario Agricultural College, Guelph.

Toronto and Georgetown stations furnish the data which are representative of the current weather in Peel County from 1923 to 1931 inclusive which influences the alfalfa seed yields there.

The data which are recorded by the Agricultural Engineering Department at the Ontario Agricultural College, Guelph, represent the prevailing weather which influenced the alfalfa seed yield in the experimental field of the Field Husbandry Department during the years 1921 to 1926 and 1930 to 1931.

Chart No. 1 represents the distribution of precipitation in Peel County in eight-day periods from June 1 to August 19 in the years 1923 to 1931 inclusive. The figures on the right hand side of the chart represent the total seed production in Peel County in corresponding years.

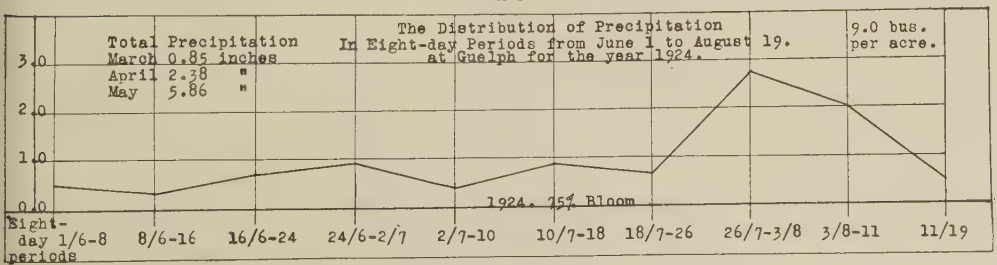
In 1926, the biggest crop of the period was harvested, and here we find the precipitation curve taking a course as nearly ideal as can be expected under Ontario conditions. Moderate precipitation in May is followed by a precipitation in early June which provides the rest of the necessary moisture without at any time being too heavy. Thereafter, follows an absolutely dry period of twelve days from June 27 to July 9, inclusive. Throughout July only light showers fall, just sufficient to prevent too dry conditions and not enough to ruin the blossoms or prevent fertilization. In August an abundance of moisture fell, and ideal pod filling conditions were thus provided.

The distribution of rainfall in 1924 and 1925 is somewhat similar to the one in 1926. The distribution in 1923, 1930 and 1931 only allows a fair seed crop. In 1927, 1928 and 1929 a most unfavorable distribution of rainfall corresponds with negligible seed production.

A chart similar to No. 1 was worked out for the data from Guelph but is not reproduced here, owing to lack of space. Only the distribution from the year 1924 is given in Chart No. 1A. In this year, the highest seed yield, nine bushels per acre, was obtained, and we observe an ideal distribution similar to the one for 1926 in Peel. The rest of the data fitted as well as the data from Peel.

Chart No. 2, A, B, C and D, represents the total monthly rainfall for June, July and August in Peel County as shown diagramatically and related to seed production in corresponding years.

CHART NO. 1A



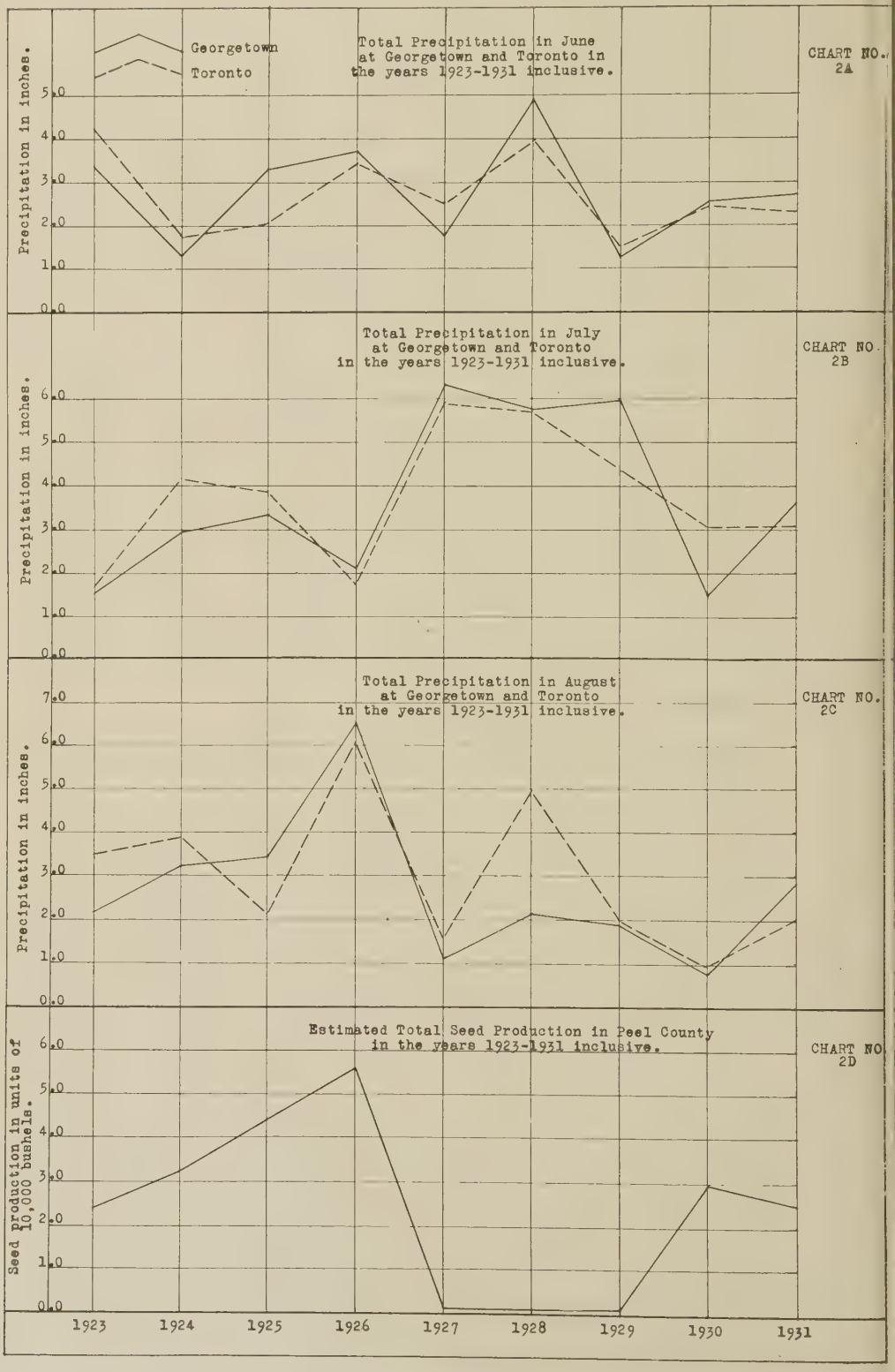

Georgetown
Toronto
Total Precipitation in June at Georgetown and Toronto in the years 1923-1931 inclusive.
CHART NO. 2A
Precipitation in inches.
Total Precipitation in July at Georgetown and Toronto in the years 1923-1931 inclusive.
CHART NO. 2B
Precipitation in inches.
Total Precipitation in August at Georgetown and Toronto in the years 1923-1931 inclusive.
CHART NO. 2C
Precipitation in inches.
Estimated Total Seed Production in Peel County in the years 1923-1931 inclusive.
CHART NO. 2D
Seed production in units of 10,000 bushels.
1923
1924
1925
1926
1927
1928
1929
1930
1931

TABLE 1.—*Analysis of sterile pollen in 9 alfalfa plants.*

	The number and Strain	Number of Flowers used	Number of "Fields" Analyzed	Total Amount Pollen	Percent Sterile Pollen	Yield of Seed in Grams in Years				REMARKS
						1928	1929	1930	1931	
From Nursery	1.g.1. Sand-Lucerne from Norway	24	125	11,696	22.5	not sel.	20.0	19.1	self-ed 0.5	The enclosure in a cage of netting made the conditions unfavourable for this plant in 1931. The 0.5 gram was obtained by rolling a few of the racemes between fingers.
	1.h.2. ditto	10	70	5,779	22.3	not sel.	5.7	not sel.	2.0	Was caged early in blooming period. Later left exposed, in 1931.
	1.h.5. ditto	11	60	3,524	63.1	0	0	0	0.1	
	1.j.1. ditto	12	60	15	60.0	0	0	0	0	Anthers small and empty except in two flowers, in one, 6 good pollen grains and 9 sterile, in another, 0 good and 3 sterile.
	3.f.7. Grimm from Montana (Westgate)	12	70	7,505	10.7	not sel.	2.4	8.4	1.1	
	3.q.16. ditto	13	65	2,520	44.9	0	0	0	0.05	
	Medicago falcata from class plot.	12	60	3,222	37.3	No record.			0.4	Westgate (*36*) mentions the comparative scarcity of pollen in Medicago falcata.
	Medicago sativa from 1–100 acre plot.	12	60	4,246	2.7	No record.			27.5	

By "field" is meant that part of the material which at one time is in view when the microscope is in focus.
Not sel. means not selected.

From this diagram it appears that the rainfall of July is the most important for the annual seed yields. A negative correlation is strongly indicated between July rainfall and the annual seed yields.

August rainfall appears to indicate slight positive correlation with the annual seed yields, and June rainfall appears to be of least importance for the annual seed yields.

It seems obvious that the seed failures in 1927, 1928 and 1929 are due to the excessive rains in July of these years. The similar data for Guelph showed the same conditions to rule as are mentioned here for Peel County. The period July 1 to July 25 appears to be the most unfavourable time for excessive rains for Peel and Wellington Counties alfalfa seed production.

Summary

1. Many modern plant breeders anticipate the raising of synthetic high-seed-producing varieties of hardy hybrid alfalfa as a means of improving the possibilities for alfalfa seed production in temperate and humid regions.

2. There is a possibility that self-fertilization of alfalfa without tripping takes place in Ontario, as well as in other regions on this continent.

3. The quantity of pollen, as well as its ability to germinate under a wide range of conditions of temperatures and moistures, seems to be one factor on which the seed production of individual plants depends.

4. Plants producing large percentages of sterile pollen are only poor seed producers. One plant was found which possessed sterile anthers and did not produce seed.

5. Thin stands of alfalfa are required to induce best seed production.

6. Climate is the limiting factor in alfalfa seed production.

7. In Wellington and Peel Counties of Ontario, the limiting climatical factor appears to be the summer rainfall, in amount and distribution. Excessive rainfall in July appears to be the cause of failures of seed production in these counties. A limited rainfall in July provides the best conditions for the local seed production.

BIBLIOGRAPHY

1. Aicher, L. C. Alfalfa seed production. Idaho Bulletin 101.
2. Alter, J. C. Alfalfa seed growing and the weather. Utah Agricultural College. Bulletin 171, 1920.
3. Brand, C. J. and Westgate, J. M. Alfalfa in cultivated rows for seed production. U.S.D.A. Circular 24, 1908.
4. Blinn, P. K. Alfalfa seed production. Colorado Bulletin 191, June 1913.
5. ———— Factors that affect alfalfa seed yields. Colorado Bulletin 257, June 1920.
6. Carlson, J. W. Seasonal behaviour of alfalfa flowers as related to seed production. Journal of the American Society of Agriculture. *20*, 542-56. June 1928.
7. ———— Artificial tripping of flowers in alfalfa in relation to seed production. Journal of the American Society of Agriculture. *22*, 780-86. September, 1930.
8. ———— and Stewart, George. Alfalfa seed production. Utah Technical Bulletin 226, May 1931.
9. Clarke, A. E. and Fryer, J. R. Seed setting in alfalfa. Scientific Agriculture *11*, 1. September, 1930.

10. Coffman, F. A. Pollination in alfalfa. Botanical Gazette. *74*, 197-203. 1922.
11. Dwyer, R. E. Lucerne breeding. Agricultural Gazette of New South Wales. *42*, Part 1, January, 1931.
12. Frandsen, H. N. Undersogelser over Bestovnings-og Befrugtningsforhold hos nogle Graes-og Baelgplantearter. Saertryk af Tidskrift for Planteavl 23. Bind. Copenhagen. 1916.
13. Fruwirth, C. Handbuch der landwirtschaftlichen Pflanzenzüchtung. Band *3*, 228. 1924
14. Hansen, N. E. Co-operative experiments of alfalfa from Siberia and European Russia. South Dakota Agricultural Experiment Station Bulletin 141, 1913.
15. Hay, W. D. Does artificial tripping of alfalfa blossoms increase seed-setting? Dominion Experiment Station, Lethbridge, Alberta. Scientific Agriculture, *5*, 9. May, 1925.
16. Helmbold, F. Untersuchungen über die Befruchtungsverhältnisse über die Bedingungen und über die Vererbung der Samenerzeugung bei Luzerne. (Medicago sativa und Bastardluzerne) Zeitschrift für Pflanzenzüchtung. Band *14*, S. 113. 1929.
17. Kirk, L. E. Self-fertilization in relation to forage crop improvement. Scientific Agriculture. *8*, 1. September, 1927.
18. Lovell, J. H. Pollination of alfalfa. American Bee Journal No. 64. April, 1924.
19. Martin, John N. The physiology of the pollen of Trifolium pratense. Contributions from the Hull Botanical Laboratorium 175. Botanical Gazette, *56*, 112-126. 1913.
20. ———— Comparative morphology of some leguminosae. Contributions from the Hull Botanical Laboratory 190. Botanical Gazette, *58*, 154-167. 1914.
21. ———— Relations of moisture to seed production in alfalfa. Agricultural Experiment Station Ames, Iowa. Research Bulletin 23. 1915.
22. Macpherson, A. Lucerne-growing for seed production in New Zealand. Journal Department of Agriculture. New Zealand. *19*. 369-371. 1918.
23. Oakly, R. A. "Medicago falcata, a yellow flowered alfalfa." U.S.D.A. Bulletin 428. 1917.
24. ———— and Westover, H. L. Commercial varieties of alfalfa. Farmers Bulletin 757. 1916.
25. Piper, C. V. Alfalfa seed production; pollination studies. U.S.D.A. Bulletin 75. April 1914.
26. Seamans, H. L. The alfalfa thrip and its effect on seed production. The Canadian Entomologist. Volume 55, No. 5. May 1923.
27. Shoesmidth, V. M. Michigan Experiment Station Bulletin 271. 1913.
28. Sladen, T. W. Pollination of alfalfa by bees of the genus Megachile. Agricultural Gazette of Canada. *5*. 125-6. 1918.
29. Southworth, W. Influences which tend to affect seed production in alfalfa and an attempt to raise a high seed producing strain by hybridization. Scientific Agriculture. *9*, No. 1. September, 1928.
30. Spafford, W. J. Lucerne-growing in South Australia. Dept. of Agriculture of South Australia. Bulletin 246. 1931.
31. Ten Eych, A. M. and Freeman, G. F. Alfalfa. Kansas Bulletin 155. 1908.
32. Torssell, Rob. Möjligheterna for luzernens förädling och fröodling. Lecture given at a conference held at the Agricultural Academy 21. October 1929.
33. Waldron, L. R. First generation crosses between two alfalfa species. Journal of the American Society of Agronomy. *12*, 133-43. April 1920.
34. ———— Cross-fertilization in alfalfa. Journal American Society of Agronomy. *11*, 259-266. September 1919.
35. Westgate, J. M. Alfalfa. Farmers Bulletin 339. 1908.
36. ———— Variegated alfalfa. U.S.D.A. Bureau of Plant Industry. Bulletin 169. 1910.
37. ————, McKee, Roland, and Ewans, M. W. Alfalfa seed production. Farmers Bulletin 495. U.S. 1912.
38. Whittet, J. N. The production of lucerne seed. Dept. of Agriculture. N.S.W.
39. Witte, H. Behaviour of the hybrids of Medicago sativa × Medicago falcata, from the standpoint of the production of types of Lucerne suitable for Central Sweden. Sveriges Utsädesforenings Tidskrift, Year XXXI, Part 5, 185-198. Malmo. 1921.
Extract in "International review of the science and practice of agriculture." Year 13, No. 4. April 1922. Rome.

PROTEIN REQUIREMENTS OF GROWING CHICKS[1]

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The ultimate object of this investigation was to determine accurately by metabolism tests the maximum protein retention in growing chicks during the early stages of life. The percentage of protein included in the majority of chick rations has heretofore been determined largely by empirical methods based on the experience of poultrymen, and by chemical analysis of food stuffs, rather than by experimental evidence of the actual protein requirements of the birds themselves. It was felt, therefore, that a measurement of protein retention under optimum conditions of growth should yield some information of fundamental importance which would assist in establishing definite feeding standards for growing chicks.

The studies herein reported represent the initial work covered, in an effort to formulate a ration and establish brooding technique which would provide such optimum conditions of growth, and eventually make possible the accurate estimation of maximum retention of protein.

SERIES NO. 1

A preliminary series of experiments (hereinafter designated 'Series No. 1') was conducted at the University of California during the summer of 1929, mainly to determine the highest and lowest levels of protein that could be fed with safety and would give reasonable increases in weight, and between these limits the point at which the highest rate of growth and most satisfactory development could be secured. These tests also gave an opportunity to improve the equipment and technique involved in the work, and thus pave the way for further tests.

Stock

For the preliminary series of experiments, day-old White Leghorn chicks were used from the Experiment Station flock at the University of California in Berkeley, Cal. No special selection was made, either among the chicks themselves or among the parent stock, for size, vigor or other qualities, except that no obviously weak or crippled birds were used.

In some of the late hatches the pens of chicks were supplemented with cross-breds, as pure Leghorns were not available in sufficient numbers. These cross-breds were mostly Leghorn × Minorca and Leghorn × Ancona. However, it was concluded that the significance of the results would not be impaired by including them along with the purebreds, as their average weekly weights, their range in weight and the variation in weight as measured by Standard Deviation and Coefficient of Variation, were closely comparable with these measurements in the Leghorns, reared in the same pen and fed on the same ration.

[1] Submitted to the University of Alberta as a thesis in partial fulfilment of the requirements for the degree of Master of Science, granted May 1931.

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Equipment

All chicks were kept for the first three weeks in storage battery brooders, heated by electricity and equipped with thermostatic control. Each compartment measured 3 feet square and accommodated 20-25 chicks. The floors were of one-half inch wire mesh, and metal pans were provided underneath to collect and remove the droppings. Dry mash and water were supplied in metal pans suspended on the outside of the pens, and were available to the chicks only through the mesh of the side walls of the brooder. At three weeks the chicks were transferred to 4 × 6 foot pens on the floor of the brooder room, the heat necessary being supplied by small electric brooders. Mash was then provided in hoppers placed inside the pens, and covered with wire netting to prevent waste.

Rations

Table 1 gives the percentage composition of the four mash mixtures fed to the various pens in this series of tests. Analysis of these mixtures gave total crude protein (N × 6.25) approximately 11, 19, 30 and 38 per cent respectively.

The entire ration in every case was fed in the form of a dry mash mixture, no whole grain and no supplement other than water being provided.

Methods

All chicks were weighed individually, daily for the first three weeks, then at weekly intervals up to six weeks, at which time records were discontinued. As it was found to be impossible to weigh every chick at the same hour every day, and as no consistent increase in weight could be detected from day to day, (due in all probability to varying amounts of material in the digestive tract) conclusions were finally based on weekly increases only.

Food consumption was measured by recording daily additions and weighing the residue at the time weekly weights of the chicks were taken.

The first lot of chicks, hatched June 3, 1929, was divided into four pens and placed on rations containing 5, 30, 55, and 80 per cent respectively of the protein supplement mixture as shown in table 1.

TABLE 1.—*Rations—pens 1, 2, 3, 4. (Series No. 1).*

	Pen 1	Pen 2, 2A	Pen 3, 3A, 3B	Pen 4, 4A
Protein supplement[1]	5	30	55	80
Alfalfa Leaf and Blossom Meal	5	5	5	5
Cod Liver Oil	2	2	2	2
Mineral Mixture[2]	5	5	5	5
Grain Mixture[3]	83	58	33	8

1 Composed of meat scrap 1-3, fish meal 1-3, powdered skim milk 1-3.
2 Bone meal 60%, limestone grit 20%, sodium chloride 20%.
3 Yellow corn meal 2-3, ground wheat 1-3.

One week later a second lot of chicks was hatched and these were used to repeat the tests with the 55 and 80 per cent protein supplement, (pens

3A and 4A) as it was felt that the optimum for rapid growth, especially in the early stages of life, lay rather in the higher than the lower levels of protein content. It soon became evident, however, that the original chicks on 80 per cent supplement were lagging behind, and that the pen on 30 per cent was not only making the most rapid growth but was thriving better than either the 55 per cent or the 80 per cent pen. The third lot of chicks, hatched June 17, was therefore used to compare the growth rate on the 30 per cent and the 55 per cent protein rations. (Pens 2A and 3B).

Rate of Growth

Table 2 sets forth for all pens in this series the average weekly weights of the chicks, and in addition for the four pens in the first lot, the average food consumption, and the efficiency of the ration as expressed in grams of food per gram of gain, weekly and for the whole period of six weeks. Figure 1 illustrates by means of graphs the growth rates for all pens in this series from one to six weeks, the average weight in grams being plotted against age in weeks.

From these it will be seen that with the first lot of chicks the ration containing 30 per cent protein supplement (Pen 2) gave the highest rate of growth, the chicks attaining a weight of 329.9 grams in 6 weeks, as compared with 299.1 for the 55 per cent ration, (Pen 3), 224.0 for the 80 per cent ration (Pen 4), and only 162.6 for the 5 per cent ration (Pen 1). The 30 per cent ration was also most economical in promoting growth, the average food per gram gain amounting to only 2.55 grams throughout the period, as compared with 2.75 for the 55 per cent ration and 3.73 for the 80 per cent. Pen 1 on 5 per cent protein made such slow growth that even with an average food consumption considerably lower than in any of the other pens, it required 3.95 grams of food to produce a gram of gain.

It will be noted that in the second and third lots of chicks, (Pens 3A and 4A, 2A and 3B) the rate of growth was slower than for corresponding pens in the first lot on identical rations, which is in accordance with the findings of Upp and Thompson (*1*), that late hatched chicks make poorer gains than early hatched chicks. With these chicks, weather conditions were in all probability responsible, as the outside temperature during June and July remained consistently high, and for several hours a day on many occasions reached 90°-95° F. in the brooding room.

Mortality and General Health

Mortality in the first lot was practically nil except in the pen on 80 per cent protein supplement. The only death in Pen 1 was due to injury. In the second lot (Pens 3A and 4A) the mortality was 50 per cent in the 80 per cent protein pen, and nil in the pen on 55 per cent protein. In the third lot (Pens 2A and 3B) mortality was high in both pens, but was probably due to the excessive heat, as in the corresponding pens in earlier hatches only one death occurred throughout the entire period.

In general health and vigor, results appeared to vary according to the amount of protein in the ration. Pens 4 and 4A (80 per cent protein supplement) showed highest mortality, severest leg weakness and poorest feathering. In rate of feathering, and in apparent health and activity,

TABLE 2.—*Rate of growth, food consumption, and economy of gains. (Series No. 1).*

PEN 1 (5%)					PEN 2 (30%)				PEN 3 (55%)				PEN 4 (80%)			
Age Weeks	No. of Chicks	Ave. Live Weight Grams	Ave. Food Cons. Grams	Grams Food Per Gram Gain	No. of Chicks	Ave. Live Weight Grams	Ave. Food Cons. Grams	Grams Food Per Gram Gain	No. of Chicks	Ave. Live Weight Grams	Ave. Food Cons. Grams	Grams Food Per Gram Gain	No. of Chicks	Ave. Live Weight Grams	Ave. Food Cons. Grams	Grams Food Per Gram Gain
1/7	15	34.1	...	..	15	33.3	...	...	16	33.7	...	..	15	32.9	...	..
1	15	42.1	20.7	2.58	15	49.9	26.3	1.59	16	52.3	25.9	1.39	15	47.9	21.7	1.44
2	15	57.5	49.0	3.18	15	82.5	65.6	2.01	16	79.4	60.9	2.25	12	69.0	66.3	3.14
3	14	79.4	71.4	3.26	15	129.1	101.3	2.17	16	126.1	101.9	2.18	12	100.2	103.8	3.33
4	14	103.4	79.3	3.30	15	182.2	123.0	2.31	16	157.9	125.0	3.93	11	137.2	125.5	3.39
5	14	127.2	114.3	4.80	15	234.6	193.3	3.69	16	216.3	181.3	3.10	9	182.0	165.6	3.69
6	14	162.6	175.0	4.94	15	329.9	246.7	2.59	15	299.1	236.0	2.85	9	224.0	231.1	5.50
			509.7	3.95			756.2	2.55			731.0	2.75			714.0	3.73

PEN 2A (30%)			PEN 3A (55%)			PEN 3B (55%)			PEN 4A (80%)		
1/7	24	35.6	25	35.8		24	35.7		26	35.7	
1	24	44.1	25	48.6		24	43.1		26	46.5	
2	21	72.7	25	70.4		20	68.0		22	60.8	
3	21	121.1	25	115.9		20	103.2		20	91.8	
4	21	163.2	25	153.6		20	131.8		16	115.6	
5	20	220.8	25	221.9		19	183.3		14	157.9	
6	20	277.9	25	278.6		19	246.1		13	191.8	

1 Figures in brackets indicate percentage of protein supplement used.
2 Average weight, and average food consumption are based on total number of chicks surviving at end of six weeks.

Pen 1 excelled all the others. In this pen there was also total absence of any signs of leg weaknesses, while this symptom appeared to some extent in all of the other pens, its incidence being in direct proportion to the protein content of the ration. Subsequent studies have suggested, however, that the high mortality, severe leg weakness and general unthriftiness in the high protein pens were due, not so much to the excessive protein but to the excess of minerals furnished by the animal proteins included, or to a disproportion in the amount of calcium and phosphorus present. Mussehl *et al* (*2*) in a report of experiments on mineral metabolism in growing chicks, present data which indicate that excessive mineral elements are detrimental to growth and injurious to health. Bethke (*3*) reports experiments which demonstrate that "the addition of excessive amounts of lime (4.5 per cent) in the form of calcium carbonate, limestone or oyster shell, to a ration containing cod liver oil and approximately 5 per cent bone meal, caused slower and more uneven growth, and increased mortality."

A chemical analysis was not made of the various ingredients of the rations used in this preliminary series, but if an estimate of the calcium and phosphorus content of the protein and mineral suplements were based on analysis of similar ingredients used in later experiments, it would run as follows:

	Total % Ca.	Total % P.	Ratio Ca:P
Pen 1	1.29	.47	2.74:1
2	2.58	1.19	2.17:1
3	3.86	1.91	2.02:1
4	5.14	2.63	1.95:1

On this basis the ration of Pen 4 undoubtedly contained an excessive amount of mineral elements, and it is reasonable to suppose that even if such an excess were not in itself injurious, it would at best tend to crowd out other elements more important in promoting growth, and thus reduce the efficiency of the ration.

As regards the optimum calcium-phosphorus ratio for growing chicks, there appears to be much conflicting evidence, and further research along these lines will be necessary before any definite conclusions can be reached. Bethke *et al* (*4*) indicate that the optimum ratio lies between 3:1 and 4:1, at which relationship the requirements for the anti-rachitic factor are found to be at a minimum. Wilgus, Jr. (*5*) on the other hand, shows that "the calcium-phosphorus ratio may vary between 1.0:1 and 2.2:1 with normal results. A ratio of 2.5:1 appears borderline, while a ratio of 3.3:1 is disastrous." Scott *et al* (*6*) report that in the absence of sunshine or other satisfactory source of vitamin D, best growth was made on a diet with a calcium-phosphorus ratio of 2:1, but that with adequate provision of the anti-rachitic element, optimum increase in weight and growth of skeleton could be secured on a ratio varying all the way from 4:1 to 3:2.

Series No. 2

In the winter of 1929 a further series of experiments (designated 'Series No. 2') was undertaken at the University of Alberta, to continue the investigation of the protein requirements of chicks.

Stock

As a basis for the work, fifty pure-bred, single-comb White Leghorn pullets of good size and type were selected from the flock of the Provincial Poultry Plant at Oliver, Alberta, to be used as parent stock for the chicks required. These pullets were placed in three separate pens, and mated to similarly selected cockerels, one to each pen. They were identified by means of numbered legbands and trap-nested throughout the laying year, the eggs being marked as collected, and the parentage of every chick recorded. Chicks were hatched as required for the test, and taken to the laboratory at the University within forty-eight hours after hatching.

Equipment

All chicks were reared for the first six weeks (that is, for the duration of the test) in electric battery brooders which were installed in the animal room of the Department of Bio-chemistry. This room is steam heated, well ventilated, and equipped with electric light and running water. These facilities insured efficient control of heat, light, air and moisture throughout the whole series of experiments. It was also possible by making use of the electric light to give a constant feeding day to all pens, lights being turned on at dusk and turned turned out every night at nine o'clock. In the morning the lights were turned on at 8.30, until the season was sufficiently advanced to make this unnecessary. The chicks therefore had a fairly constant feeding day of 12½ hours throughout.

During the course of the experiment several types of electric battery brooders were used, in an attempt to find one which would best meet the requirements for control of the factors under consideration. The broooder used for the first lot of chicks (Pens 1, 2, 3 and 4, hatched December 6, 1929) proved satisfactory for the general comfort of the birds, but towards the end of the third week it was found that the larger birds could not pass their heads through the mesh of the side walls to reach the mash and water, and consequently were being starved. This fact undoubtedly accounts for the comparatively low figures for average weight and for food consumption, which appear at three weeks in the records for these four pens. To overcome the difficulty in feeding, these birds were moved at three weeks to a second brooder, equipped with adjustable openings on the sides, thus making it possible for all the birds to feed comfortably until the end of the experiment. The feed pans in this second brooder were also constructed in such a way, as to practically eliminate the possibility of waste. For the second lot of chicks (Pens 7, 8, 9, 10, hatched Dec. 30, 1929) the first brooder was used again, the feeding difficulties in the latter part of the test being overcome by placing the pens inside the compartments, with wire netting covering the mash. Food wastage with this method was negligible and records for food consumption are thus fairly accurate, except for the last week when a certain amount of spillage occurred.

For the third lot of chicks (Pens 13, 14, 15 and 20, hatched Feb. 14, 1930) a third brooder was installed, similar to brooder No. 1, but provided with adjustable openings for feeding. In this equipment again, however, it was impossible to prevent a slight wastage of feed, so that records of mash consumption appear slightly higher than would be the case with perfect equipment. A preliminary test of protein retention was undertaken with Pens 14 and 20, which for this purpose were moved at four weeks to small compartments measuring 2 × 2½ feet, heated by electric lamps and equipped with special means of controlling intake of food and collecting the feces. The results of this test were not made use of, but it should be noted that growth rate in these two pens was retarded after moving, (compare average weights at 4, 5 and 6 weeks with those of earlier pens on similar ration) due in all probability to the close confinement and excessive heat in the small test pens.

Rations

Table 3 gives the percentage composition of the rations employed in Series No. 2, and the partial chemical analysis of the protein and mineral supplements used.

The rations for pens 7, 8 and 9 (lot 2) of this series, and 13, 14 and 15 (lot 3) are identical with those of pens 1, 2 and 3 respectively (lot 1) except for an increase in mineral supplement in pens 7 and 13. While in all cases the calcium; phosphorus ratio was kept at approximately the same level, it was concluded when the second lot was hatched that possibly with only 20 per cent protein supplement the minerals added for pen 1 were not sufficient to provide the optimum total. In the second and third lots, therefore, mineral additions were made to the ration for the pens on 20 per cent protein supplement, so as to bring the total calcium and phosphorus up to the same level as in the 40 per cent pens. The marked increase in growth of the chicks in pens 7 and 13 over those in pen 1, demonstrates the beneficial effect of this increase.

It will be noted that the pens on 60 per cent protein supplement received in all cases a higher total of minerals than the other two, but as the phosphorus could not have been reduced without removing some of the protein supplement, the only means by which the calcium-phosphorus ratio could be maintained was to add calcium in sufficient amounts to balance the phosphorus already present.

The ration for pens 4 and 20 (25 per cent protein supplement) which carries a high proportion of yellow corn (45 per cent as against 20 per cent in the other pens) and also contains .5 per cent more of cod liver oil, was designed originally, not for comparison with the others included in this report, but as a "normal" ration suitable for practical purposes, and was being used in another series of experiments. However, as the main object of this present investigation was to secure maximum growth, and as the first pen on this "normal" ration made better growth than any of the others studied, the results have been included herein, and the ration itself used later as a basis for protein retention tests.

TABLE 3.—*Percentage composition of rations. (Series No. 2.).*

	Pen 1	Pens 7, 13	Pens 2, 8, 14	Pens 3, 9, 15	Pens 4, 20
Yellow Cornmeal	20	20	20	20	45
Alfalfa Leaf-and-Blossom Meal	5	5	5	5	5
Wheat Bran	5	5	5	5	5
Salt (NaCl)	1	1	1	1	1
Cod Liver Oil	1	1	1	1	1.5
Basal	32	32	32	32	
Protein Supplement[1]	20	20	40	60	25
Calcium Carbonate[2]	2	4	4	6	2.5
Fine Oatmeal	46	39	24	2	15
Bone Meal[3]	–	5	–	–	–
	100	100	100	100	100
Percent Protein in Supplement	11.66	11.66	23.32	34.98	14.57
Percent Ca. and P.	Ca. P.	Ca. P.	Ca. P.	Ca. P.	Ca. P.
	1.84 .59	3.70 1.15	3.68 1.17	5.51 1.76	2.30 .73
Ratio Ca.: P.	3.12:1	3.21:1	3.14:1	3.13:1	3.15:1

PEN 10
(Decreasing proportions of Protein Supplement)

Week	1	2	3	4	5	6
Basal (as in pen 1)	32	32	32	32	32	32
Protein Supplement	60	50	40	30	20	10
Calcium Carbonate	6	5	4	4	4	4
Bone Meal	—	—	—	2.5	5	8
Fine Oatmeal	2	13	24	31.5	39	46
	100	100	100	100	100	100
Ca. in protein and mineral sipplement	5.51	4.60	3.68	3.69	3.70	3.82
P. in protein and mineral supplement	1.76	1.47	1.17	1.16	1.15	1.17
Ratio Ca.:P.	3.13:1	3.13:1	3.14:1	3.20:1	3.20:1	3.30:1

1 Protein Supplement mixture:

	Protein Content	Proportion in Mixture	Total Percentage in Mixture Protein	Ca.	P.
Pilchard Meal	72.5%	50%	36.3	2.80	1.56
Beef Scrap	50%	25%	12.5	2.15	1.15
Powdered skim milk	38%	25%	9.5	.29	.22
		100%	58.3	5.24	2.93

2 Marble grit analysing 39.55% calcium, free from magnesium.
3 Analysis, calcium 21.49%, phosphorus 11.11%.

The rations for pen 10 were designed to test the theory that the chick's protein requirements are highest at hatching, and decrease as growth proceeds. In order to maintain optimum balance of calcium and phosphorus, it was necessary to adjust the amount of mineral supplements weekly with each change in the protein level. By adding varying amounts of bone-meal and limestone flour, the ratio of calcium to phosphorus was maintained at approximately 3:1 throughout, although in the mixtures

for the first two weeks, on account of the high content of animal proteins, the total content of these two minerals was of necessity higher than desirable.

In pens 1, 2, 3 and 4 (lot 1) the only supplement other than water fed with the experimental mash, was a silica grit. In subsequent lots of chicks the silica grit was omitted and the calcium carbonate supplement (marble grit) was included in the mash in fine granular form instead of in a powder, as in the first lot. In studies of the mechanism and function of grit, Buckner, Martin and Peter (7) found that when fed in addition to a grain, mash and buttermilk ration, grit did not materially change the rate of growth in White Leghorns up to 30 weeks of age, and did not influence egg production up to eight months. Bethke and Kennard (8) also found no benefit from the feeding of granite grit up to twelve weeks and concluded that its value lay in providing a source of essential minerals if the ration was otherwise deficient in these. It was concluded, therefore, that the rate of growth would not be materially influenced by omitting hard grit from the ration, and at the same time feeding would be simplified.

Methods

All chicks were weighed individually as soon as received, and were distributed in groups, made up in such a way that the average weight and the range in weight were as nearly alike as possible in each. Weights were then taken individually for all chicks at weekly periods from date of hatching. Food consumption was also recorded weekly for each pen, the residue in the pans being weighed back and recorded at the time the chicks were weighed.

Some apparent discrepancies appear as between the different lots, in the records of food consumption for the first week. These are due principally to the fact that the chicks in Lots 1 and 2 were not fed for 24 hours after date of hatching, and those in Lot 3 were fed as soon as hatched. The first week therefore consisted of only six feeding days for the pens in Lots 1 and 2, and of seven feeding days for the pens in Lot 3.

Data were compiled, and are submitted below, showing the results secured in growth, food consumption and economy of gains for all pens in this series. Average weekly live weights were based on the total number of surviving chicks in each pen at the end of the six weeks period. In pens where any mortality occurred, the average weekly food consumption was computed by deducting weekly from the total for each pen, the estimated amount eaten by the chicks which died, on the basis of the relation of their weight at time of death to the total weight of the chicks in the pen.

Rate of Growth

In table 4 are set forth the average weekly weights up to six weeks for all pens in the three lots of this series. Figure 2 illustrates graphically these values for the three groups of pens on 20, 40 and 60 per cent protein supplement, also for pens 4 and 20 on the "normal" ration, (25 per cent protein) and for pen 10 on decreasing protein content.

TABLE 4.—*Rate of growth.* (*Series No. 2*).

Lot 1 Hatched December 6, 1929

Pen 1 (20%)*			Pen 2 (40%)		Pen 3 (60%)		"Normal" Ration Pen 4 (25%)	
Age Weeks	No. of Chicks	Ave.† Live Wt. Grams	No. of Chicks	Ave. Live Wt. Grams	No. of Chicks	Ave. Live Wt. Grams	No. of Chicks	Ave. Live Wt. Grams
1/7	15	34.4	19	34.2	20	34.1	9	33.8
1	15	48.2	19	53.0	20	56.0	9	52.1
2	15	77.1	19	96.2	15	96.9	9	95.5
3	15	105.8	19	144.0	15	143.0	9	141.2
4	15	156.3	18	211.6	13	205.4	9	224.6
5	15	230.3	18	303.9	13	285.4	9	325.2
6	15	317.2	18	416.1	13	383.1	9	445.6

Lot 2 Hatched December 30, 1929

Pen 7 (20%)			Pen 8 (40%)		Pen 9 (60%)		Decr. prot. cont. Pen 10 (60-10%)	
1/7	17	33.8	16	34.0	15	33.8	16	33.8
1	17	56.8	16	58.8	15	55.1	16	56.8
2	17	86.9	16	99.9	15	86.8	16	90.2
3	17	141.5	16	164.3	14	136.2	16	141.5
4	17	197.7	16	223.6	14	171.9	16	206.6
5	17	285.6	16	319.1	14	246.6	16	306.2
6	17	370.0	16	441.3	14	343.4	16	417.1

Lot 3 Hatched February 14, 1930

Pen 13 (20%)			Pen 14 (40%)		Pen 15 (60%)		"Normal" Ration Pen 20 (25%)	
1/7	18	37.2	16	37.4	18	38.2	17	39.3
1	18	57.1	16	62.8	18	59.7	17	61.1
2	18	91.2	16	106.2	17	93.3	17	105.3
3	18	137.2	16	159.1	15	126.8	16	157.6
4	18	206.8	16	243.3	15	184.9	16	239.8
5	18	294.4	16	338.4	15	257.6	16	331.4
6	18	374.7	16	425.3	15	339.2	16	407.9

* Figures in brackets indicate percentage of protein supplement used.

† Based on total number of chicks surviving at end of six weeks.

In the first lot, hatched December 6, 1929, it will be noted that the average rate of growth in pen 1 (20 per cent protein) fell considerably below the level of the other two, (average weight, 317.2 grams at six weeks, as compared with 416.1 and 383.1 grams). In both the second and third lots, however, when the mineral content of the 20 per cent pens was increased, the average weights at six weeks (370.0 grams and 374.7 grams respectively) not only exceeded those of the 60 per cent pens (343.4 grams and 339.2 grams, respectively) but were considerably higher than in the original 20 per cent pen. Of the three levels of protein compared, however, the pens on 40 per cent consistently made the highest gains, attaining average weights of 416.1, 441.3, and 425.3 grams respectively in the three lots raised. Equally satisfactory growth, was made by the pens on the "normal" ration containing 25 per cent protein, the

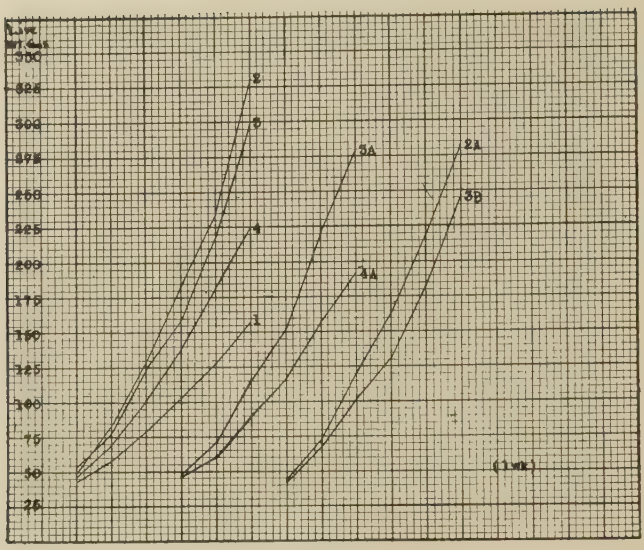

Figure 1.

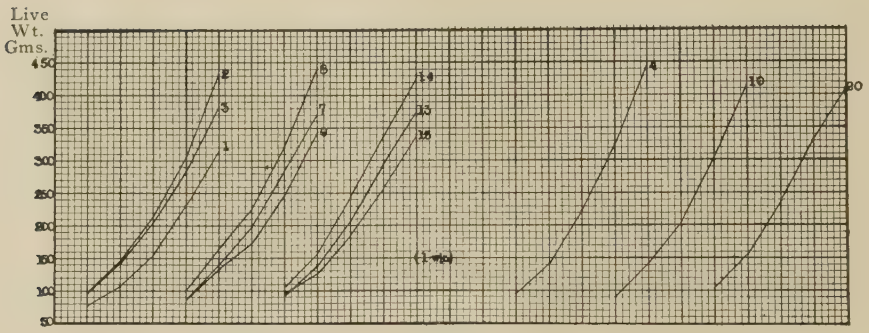

Figure 2.

average weight at six weeks being 445.6 grams for pen 4, and 407.9[3] for pen 20. In comparison with the pens on 20 per cent protein, the difference in favor of the "normal" ration is considerably greater than might reasonably be attributed to an additional 5 per cent of protein supplement, but may be due in part to the higher content of yellow corn-meal and of cod liver oil.

Pen 10, which received decreasing proportions of protein supplement, from 60 per cent the first week, reduced by 10 per cent each week down to 10 per cent in the sixth week, made highly satisfactory gains and reached an average weight of 417.1 grams at six weeks. This is on a level with the growth in the 40 per cent pen, hatched and reared at the same time, but comparison with the pens on the "normal" rations suggests that if the yellow corn and the cod liver oil content of pen 10 were made up to the levels of pen 4, the growth rate on the decreasing protein levels might exceed that of the best pens in the series. It is

[3]Low figure due to excessive heat as noted previously.

possible also that if the reduction in protein content were made less rapidly than at the rate of 10 per cent each week, there might be an even more marked increase in weight throughout the period of the test.

It will be noted that the average weekly weights as calculated and set forth above do not take into consideration the proportion of male and female chicks in the various pens studied, although such a consideration is of importance in establishing a uniform basis for comparison. It was found, however, by using the conversion factor as suggested by Ackerson and Mussehl (*9*) that the average weights at six weeks, when converted to an all-male basis, placed the four pens in each lot in the same sequence as before, so that the conclusions drawn with regard to the comparative effect of the various rations employed remain unaffected by correcting for sex ratio.

Variability in Growth Rate

In spite of the fact that all the chicks in these experiments were of the same breed and strain and were hatched from a small group of selected and related parents, there appeared a very wide variation in rate of growth, even between individuals in the same pen and fed on the same rations. The lowest weight at six weeks for any bird (170 grams) is to be found in Pen 9 (60 per cent protein supplement) and the highest (525 grams) in pen 8 (40 per cent protein supplement) while individuals of 400 grams and over occur at every protein level included. In none of the pens on the 40 per cent protein supplement, however, and in none on the "normal" ration were there any birds weighing less than 300 grams at six weeks.

While variability in growth rate is highest in the pens on very high protein, there is still a wide enough range of difference even in the most uniform groups (pens on 40 per cent protein supplement) to suggest the operation of a heritable factor for "growth impulse", or the ability to utilize protein for the formation of tissue. Data are being compiled from records of growth of the birds used in these experiments, which may throw some light on the question of the possible inheritance of factors determining just how rapidly a bird may be expected to grow, or to what ultimate size it may attain under a given set of conditions. Such data should be of interest in supplementing these present studies of what the optimum conditions are which will enable a bird to realize most fully its inherent potentialities for growth.

Weekly Percentage Increase

In table 5 and figure 3, are shown the weekly percentage increases in weight, which indicate for the pens in Lots 1 and 3 a fairly rapid rise from the first to the second week, then a gradual decline in rate to the end of the six weeks period. The percentage increase between the first and second week is specially marked in Lot 1. The fact that there is a drop instead of a rise at this period in all pens in Lot 2, hatched on December 30th, may be due to the fact that on the night of January 14th, the temperature of the room fell to a very low level. The birds became chilled, and may have suffered a temporary set-back in growth. In the

Figure 3.

first lot the sharp decline from the second to the third week may be accounted for by the feeding difficulties already described, which occurred during the third week. Between the third and fourth weeks there is a compensating rise in the curve, followed by the gradual decline to the end of the period found in the other pens.

The curves for weekly rate of increase in pens 4 and 20 ("normal" ration) display the same sharp rise between the first and second week that is to be found in most of the other pens, and the drop at three weeks common to all but the pens of Lot 2 hatched December 30th.

The curve illustrating weekly percentage increase in weight for Pen 10, shows a more even and gradual decline in rate during the six weeks than that of any of the other pens in the entire series of experiments.

Food Consumption and Economy of Gains

In table 5 are included also records of average food consumption, weekly and for the entire period for pens in this series. In comparing the figures for the pens on 20, 40 and 60 per cent protein supplement it will be noted that average food consumption increases with protein content, or possibly with mineral content, which in the first lot followed the protein level. The influence of the mineral content is suggested also by the fact that the 20 per cent pen in the second lot consumed more food per chick, and also per gram of chick, than the 20 per cent pen in the first lot, the only difference in the ration for these two pens being a higher mineral level in the second lot.

The comparative economy of gains, or efficiency of the various rations employed, is expressed in grams of food consumed per gram of gain in weight,

TABLE 5.—*Weekly percent gains, food consumption, economy of gains. (Series No. 2).*

Lot 1 Hatched December 6, 1929

Age Weeks	Pen 1 (20%) % Gain	Pen 1 (20%) Ave. Food Cons. Grams	Pen 2 (40%) % Gain	Pen 2 (40%) Ave. Food Cons. Grams	Pen 3 (60%) % Gain	Pen 3 (60%) Ave. Food Cons. Grams	Normal Ration Pen 4 (25%) % Gain	Normal Ration Pen 4 (25%) Ave. Food Cons. Grams
1/7	...	...	...	...	...	...	...	...
1	40.1	26.6	54.9	25.4	64.2	21.6	54.1	29.2
2	59.9	55.1	81.5	70.0	73.0	90.1	83.3	80.2
3	37.2	75.1	49.6	99.2	47.6	126.6	47.8	95.5
4	47.7	123.1	46.9	150.0	43.6	200.7	59.1	190.0
5	47.3	176.6	43.6	187.0	38.9	243.9	44.8	271.7
6	37.7	196.3	36.9	231.0	34.2	284.6	37.0	296.7
	Gms. food per gm. gain 2.31		Gms. food per gm. gain 2.00		Gms. food per gm. gain 2.77		Gms. food per gm. gain 2.34	

Lot 2 Hatched December 30, 1929

	Pen 7 (20%)		Pen 8 (40%)		Pen 9 (60%)		Decr. prot. cont. Pen 10 (60-10%)	
1/7	...	...	...	...	...	...	...	...
1	68.0	32.1	72.9	21.9	63.0	27.1	68.0	30.6
2	53.0	83.9	69.9	82.5	57.5	88.1	58.8	78.1
3	62.8	128.6	64.5	175.3	56.9	168.6	56.8	120.0
4	39.7	164.7	36.1	185.6	26.2	207.9	46.0	179.1
5	44.5	227.4	42.7	239.7	43.5	280.0	48.2	242.2
6	29.6	305.9	38.3	325.0	39.2	328.6	36.2	325.0
	Gms. food per gm. gain 2.80		Gms. food per gm. gain 2.53		Gms. food per gm. gain 3.55		Gms. food per gm. gain 2.54	

Lot 3 Hatched February 14, 1930

	Pen 13 (20%)		Pen 14 (40%)		Pen 15 (60%)		Normal Ration Pen 20 (25%)	
1/7	...	...	...	...	...	...	...	...
1	53.5	43.1	67.9	48.1	56.3	46.7	55.5	34.5
2	59.7	105.0	69.1	120.6	56.3	108.9	72.3	107.1
3	50.4	135.9	49.8	138.8	35.9	149.4	49.7	123.7
4	50.7	177.7	52.9	190.0	45.9	200.0	52.1	190.9
5	42.3	223.6	39.1	225.3	39.3	225.6	38.2	210.6
6	27.3	270.3	25.6	231.9	31.7	292.6	23.1	226.3
	Gms. food per gm. gain 2.83		Gms. food per gm. gain 2.46		Gms. food per gm. gain 3.40		Gms. food per gm. gain 2.42	

for the six weeks period. Of the three levels of protein used it will be seen that in all cases the 40 per cent pens made the most economical gains, requiring 2.00, 2.53 and 2.46 grams of food respectively, per gram of gain. These are followed by the 20 per cent pens, which required 2.31, 2.80 and 2.83 grams respectively, while the 60 per cent pens showed a much lower

efficiency requiring 2.77, 3.55 and 3.40 grams respectively, to produce one gram of gain.

On the "normal" ration, food per gram gain amounted to 2.34 and 2.42, in the two pens raised, and on decreasing protein content (pen 10) it was 2.54 grams. Economy of gains on these rations was, therefore, on a level with that of the 40 per cent protein pens, with the exception of pen 2, where the efficiency appeared to be exceptionally high.

Mortality and General Health

Mortality in all pens of this series was negligible except in those on 60 per cent protein supplement. This is in agreement with the results secured in the preliminary studies herein reported, and appears to support the theory that very high levels of protein not only do not promote rapid growth but are actually injurious to health. As indicated before, however, excessive mineral content, may be partly responsible for poor results with the high protein rations.

In strength of bone, growth of feathers and constitutional vigor, the birds on the "normal" ration appeared to be somewhat superior to the others, although all apparently developed normally, except those on 60 per cent protein. These latter were unkempt in appearance and less active and vigorous than the others. The faeces were also abnormally moist, and this condition was accompanied by excessive thirst and high food consumption.

One chick (No. 123 in Pen 7) developed a peculiar type of paralysis at the age of three weeks. The bird was observed to be walking on its hocks, the leg muscles being very weak and the toes curled in and apparently paralysed (figures 4 and 5). In other respects the bird appeared to be in normal health, its appetite was good, and the symptoms lasted only for about ten days, after which they spontaneously disappeared.

Figure 4.

Figure 5.

Norris *et al* (*10*) who found what appears to be exactly the same type of paralysis in experimental chicks, suggest this disease is due to the absence of a hitherto unrecognized vitamin thought to exist in milk. On the other hand Hart *et al* (*11*) report a similar condition among chicks

supplied with liquid milk *ad libitum*. However, attempts to induce such a type of paralysis experimentally have hitherto apparently yielded no results, so that the exact cause still remains a matter of conjecture.

Apart from the one case of paralysis cited above, no evidence of leg weakness of any kind was observed in any of the pens in this second series of experiments, and no tail-picking or cannibalism occurred throughout the entire period of the tests.

Summary and Conclusions

1. Preliminary tests were made, to determine the highest and lowest possible proportions of protein which would yield normal growth and development in White Leghorn chicks up to six weeks of age. These showed that of the four levels of protein supplement used, the lowest (5 per cent) gave extremely slow growth (average weight in one pen 162.6 grams at six weeks) but good health and low mortality; the highest (80 per cent) gave slightly better growth with average weights of 224.0 and 191.8 grams respectively, in two pens reared, but poor feathering, extreme leg-weakness and high mortality. Three pens on 55 per cent supplement developed normally, and attained average weights of 299.1, 278.6 and 246.1 grams respectively, while the two pens on 30 per cent supplement weighed 329.9 and 277.9 grams, respectively, at six weeks of age.

Economy of gains, as measured by increase in weight per unit of food consumed, was highest in the 30 per cent pens, but was followed closely by those on 55 per cent supplement. The 80 per cent ration was much lower in efficiency, but was slightly better than the 5 per cent ration, which was thus the poorest both in respect to absolute growth and to economy of gains.

2. A second series of tests showed that for the first six weeks a ration containing 40 per cent protein supplement (total crude protein 23.32 per cent) was not only perfectly satisfactory as far as strength of bone, normal feathering, and general health were concerned, but gave more rapid growth, greater uniformity and more economical gains than similar rations containing either lower (20 per cent) or higher (60 per cent levels of protein supplement. Average weight at six weeks of the best pen on 40 per cent protein was 441.3 grams, as compared with 374.7 grams for the 20 per cent ration and 383.1 grams for the 60 per cent ration.

An average weight of 417.1 grams at six weeks was secured with a pen on decreasing proportions of protein supplement, from 60 per cent during the first week down to 10 per cent during the sixth week, while average weights of 445.6 and 407.9 grams respectively, were attained by two pens on a ration high in yellow corn and containing 25 per cent protein supplement.

In all pens in this second series a standard protein supplement mixture was used, consisting of 50 per cent pilchard meal, 25 per cent beef scrap and 25 per cent powdered skim milk. Ca : P ratio was also maintained at a constant level of approximately 3 : 1 throughout.

Mortality was practically nil, except in one of the pens on 60 per cent protein supplement. There was no evidence of rickets or other forms of leg weakness, even in the pens on very high protein, bone development being exceptionally good throughout. Feather growth was normal, except in a few individuals in the high protein pens, and no evidence of tail-picking or cannibalism occurred in any of the pens.

Acknowledgments

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LITERATURE CITED

1. Upp, Chas. W. and Thompson, R. B. "Influence of time of hatch on.... Rate of growth of chicks", Okla. A. & M. College Bull. 167 Oct. 1927.
2. Mussehl, F. E., Blish, M. J. and Ackerson, C. W. "Mineral metabolism of the growing chick", Poultry Science, vol. *6*: *5*, 1927.
3. Bethke, R. M. Ohio Exp. Sta. Bull. July-August, 1927.
4. Bethke, R. M., Kennard, D. C., Kick, C. H. and Zinzalian, G. "The calcium: phosphorus relationship in the nutrition of growing chicks". Poultry Science, *8*: *5*, 1929.
5. Wilgus, H. S. Jr. "The quantitative requirements of the growing chick for calcium and phosphorus". Poultry Science, *10*, 3, 1931 .
6. Scott, H. T., Hart, E. B., Halpin, J. S., and Holmes, C. E. Wisconsin Bulletin 410, 1930.
7. Buckner, G. D., Martin, J. H. and Peter, A. M. "Concerning the growth of chickens raised without grit", Poultry Science, *5*: *5*, 1926.
8. Bethke, R. M. and Kennard, D. C. "Does the growing chick require grit?" Poultry Science, *5*: 6. 1926.
9. Ackerson, C. W. and Mussehl, F. E. "Sex differences in the normal growth rate of chicks". Journal of Agric. Research, *40*: 863-866. May 1930.
10. Norris, L. C., Heuser, G. F. and Wilgus, H. S. Jr. "Is the chief value of milk for feeding poultry due to the presence of a new vitamin?" Poultry Science, *9*: 2, 1930.
11. Hart, E. B., Kletzien, S. W. F. and Scott, H. T. "The alleged new vitamin in milk for poultry", Poultry Science, *9*: *5*, 1930.

RESULTATS D'UNE ENQUETE CONDUITE SUR 74 VERGERS DU QUEBEC EN 1920

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La Division de l'Economie Agricole organisée par le ministère fédéral de l'Agriculture vers la fin de l'année 1929, entreprit de faire en 1930 une étude de la production et de la vente des pommes dans les principaux districts de l'est du Canada où l'exploitation des vergers constitue la principale source de revenus des cultivateurs de ces districts. Cette étude fut continuée en 1931 et elle le sera, si possible, en 1932 afin d'obtenir des données pour trois années consécutives.

Les ministères provinciaux de l'Agriculture du Québec, de l'Ontario et de la Nouvelle Ecosse donnèrent au personnel de la Division de l'Economie Agricole leur bienveillante coopération pour conduire ce travail à bonne fin.

La production moyenne annuelle de pommes dans la province de Québec ne fut que de 127,666 barils au cours de la période de cinq ans de 1926-30 et de 187,180 barils en 1929, ce qui ne représente qu'environ 4.8 pour cent de la récolte totale de pommes au Canada.

Afin d'obtenir des renseignements précis sur l'organisation des fermes et l'exploitation des vergers du Québec, la Division de l'Economie Agricole fit, en 1929, une enquête sur 74 fermes dans les districts de St. Hilaire, Rougemont et Abbotsford qui se trouvent situés à environ 30 à 40 milles de Montréal. Ce sont les districts qui fournissent la plus forte production de pommes dans la province de Québec. Les résultats de cette analyse ont déjà été publiés partiellement dans l'Economiste Agricole, revue mensuelle de la Division de l'Economie Agricole.

Tableau 1.—*Classement des 74 fermes du Québec étudiées dans cette enquête.*

Groupe de fermes	No. de fermes dans chaque groupe	Etendue moyenne des vergers en rapport	Etendue moyenne des vergers non en rapport	Valeur moyenne des terres et vergers (roulant compris)
		arpents	arpents	$
4 – 8 arpents	21	5.9	6.0	12,111
9 – 13 "	19	10.5	7.4	14,871
14 – 18 "	5	16.2	7.4	17,495
19 – 23 "	7	20.0	11.4	20,187
24 – 28 "	4	24.8	15.5	29,454
29 – 33 "	8	30.0	6.0	23,799
34 – 38 "	3	35.3	17.0	27,623
39 et plus "	7	48.9	17.8	41,844
Totaux et moyennes	74	18.0	9.0	19,590

Les chiffres donnés dans ce tableau indiquent que la valeur moyenne de ces fermes en 1929 était très élevée. Evidemment ce n'est là qu'une évaluation approximative faite par les propriétaires de ces vergers qui recevaient alors de bons prix pour leurs pommes. La plupart d'entre eux

ayant hérité de ces fermes avouent qu'ils ne seraient pas disposés à vendre leur propriété à moins d'en obtenir un bon prix. Comme il se fait très peu de ventes ou d'achats de ces fermes dans ces districts, il est bien difficile d'établir la valeur commerciale exacte de ces fermes. Il faut tenir compte aussi du fait que cette valeur moyenne comprend les bâtisses de fermes ainsi que le bétail et les machines agricoles. Il fut un temps où l'on croyait que ces trois districts étaient les seuls endroits favorables à la production des pommes dans le Québec, mais l'on se rend maintenant compte qu'il existe dans cette province plusieurs autres régions où l'on peut faire avantageusement l'exploitation des vergers. Ces nouveaux districts sont un peu plus éloignés de la ville de Montréal, principal centre de consommation au Canada, mais ils offrent l'avantage de contenir de grandes superficies de terrain bon marché et favorable à cette culture. En 1930, cette étude sur l'exploitation des vergers fut aussi poursuivie dans les nouveaux districts à pommes des comtés Huntingdon et Chateauguay. Il serait intéressant de connaître la différence qui existe dans la valeur des terres à vergers situées dans ces nouveaux districts et celles des trois districts étudiés en 1929, St. Hilaire, Hougement et Abbotsford. Il est évident qu'il en coûte moins cher pour planter un verger et l'entretenir jusqu'à ce qu'il soit en rapport et paie ses frais que d'acheter un verger en rapport dans les anciens districts, mais il y a toujours plusieurs éléments de risques et c'est ce qui explique que beaucoup de pomiculteurs des anciens districts préfèrent garder leurs vergers ou l'agrandir en achetant à un haut prix quelques acres de vergers en rapport dans le voisinage plutôt que d'aller s'établir dans les nouveaux districts. C'est plus souvent préférences personnelles que proposition d'affaires.

TABLEAU 2.—*Comparaison de la grandeur moyenne des terres et du capital placé sur les fermes.*

Item		Nouvelle Ecosse	Québec	Ontario
Nombre de fermes		158	74	148
Etendue moyenne des fermes	acres*	165.0	82.1	115.9
Etendue moyenne des vergers en rapport	"	20.0	15.2	21.1
Etendue moyenne des jeunes vergers	"	4.7	7.6	3.4
Valeur totale des fermes		$16,166	$19,590	$20,028
Valeur de la terre et des bâtisses		12,890	16,907	16,585
Valeur du bétail		1,356	715	1,331
Valeur des instruments et machines		1,389	1,675	1,697
Valeur des fourrages et des fournitures de ferme		120	84	174
Capital de roulement		411	210	241

* Dans ce tableau l'étendue des fermes et des vergers du Québec a été convertie en acres afin d'avoir une base unique de comparaison Une acre est égale à 1.184 arpent soit environ 1–6 de plus qu'un arpent.

Ce tableau indique que la grandeur moyenne des fermes étudiées dans cette enquête est moindre dans le Québec que dans l'Ontario et la Nouvelle Ecosse. L'étendue des vergers en rapport qui est de 18 arpents dans Québec soit environ 15.2 acres est aussi inférieure à celle des vergers de l'Ontario et de la Nouvelle Ecosse respectivement de 21 et de 20 acres. Par contre l'étendue des jeunes vergers est à peu près le double dans le Québec. Quant au capital placé sur les fermes il est à peu près le même dans le Québec et l'Ontario, tandis que la valeur des fermes de la Nouvelle

Ecosse est moindre soit $16,166 contre $19,590 dans le Québec et $20,028 dans l'Ontario.

TABLEAU 3.—*Moyenne des revenus et des dépenses des fermes étudiées en 1929.*

Genre de Revenus	Nouvelle Ecosse	Québec	Ontario
Revenus provenant de la vente des pommes	$2,653	$2,402	$2,402
Revenus provenant du bétail, de l'augmentation de l'inventaire, etc.	1,545	984	2,088
Revenu total	4,198	3,386	4,490
Dépenses courantes	3,524	2,016	2,950
Dépréciation des instruments et des bâtisses	350	413	378
Dépenses totales	3,874	2,429	3,328
Bénéfices nets des fermes (farm income)	324	957	1,162
Intérêt sur le capital de ferme à 5%	808	979	1,001
Rémunération du travail de l'exploitant (labour income)	− 484	− 22	161

Ce tableau indique que les revenus provenant de la vente des pommes sont sensiblement les mêmes dans les trois provinces. Les revenus du bétail dans Québec sont à peu près la moitié de ceux de l'Ontario et de la Nouvelle Ecosse. Les revenus divers sont plus élevés dans le Québec et proviennent principalement de la vente du sucre et du sirop d'érable. Les revenus totaux des fermes du Québec sont en moyenne inférieurs à ceux de l'Ontario et de la Nouvelle-Ecosse de même que les dépenses.

Les bénéfices nets des fermes de l'Ontario sont en moyenne de $1,162, ceux du Québec de $957 et ceux de la Nouvelle Ecosse de $324. Il est à noter cependant, qu'en 1929 la récolte de pommes de la Nouvelle Ecosse fut très abondante et de qualité médiocre, ce qui explique que les prix furent très bas et par suite les revenus anormalement faibles.

Après avoir déduit des revenus nets 5 pour cent d'intérêt sur le capital total placé sur les fermes, il reste $161 aux exploitants de fermes de l'Ontario comme rémunération de leur travail, tandis que ceux du Québec sont à court de $22 et ceux de la Nouvelle-Ecosse de $484.

En faisant l'analyse des records individuels de 74 fermes du Québec on trouve que sur 14 de ces fermes les revenus ne furent pas suffisants pour couvrir les dépenses courantes et la dépréciation, et les pertes varient de $13 à $2,967. Sur les 60 fermes qui restent, 26 cultivateurs eurent un revenu net variant de $68 à $1,000; 22 de $1,000 à $2,000; 7 de $2,000 à $3,000; 3 de $3,000 à $4,000 et 2 cultivateurs se firent un revenu net dépassant $4,500.

Le classement de ces fermes selon la rémunération du travail de l'exploitant c'est-à-dire après avoir déduit du revenu net 5 pour cent d'intérêt sur le capital de ferme, montre que 32 cultivateurs n'obtinrent aucune rémunération pour leur travail personnel, tandis que les 42 autres réussirent à se faire un salaire variant de quelques dollars à $3,413. Sur

ce nombre 22 cultivateurs obtinrent comme rémunération de leur travail moins de $500; 10 obtinrent de $500 à $1,000; 9 de $1,000 à $1,500 et 5 se firent un salaire variant de $1,500 à $3,500.

Il ne faut pas conclure de là, cependant, qu'en 1929 les cultivateurs qui, après avoir payé tous leurs frais d'exploitations et avoir déduit 5 pour cent d'intérêt sur leur capital, n'ayant pas réussi à se faire un salaire quelconque pour leur travail, se sont endettés d'autant, car ils eurent en plus l'usage de leur maison ainsi que des produits agricoles récoltés sur leur ferme.

Ceux qui n'ont qu'une hypothèque partielle sur leur terre ont pu faire des épargnes de même que ceux qui n'ont pas d'intérêt à payer. De plus, le montant de $413 alloué pour la dépréciation des bâtisses et des instruments n'est pas déboursé en argent chaque année; c'est comme une réserve ou un fond d'amortissement. Il faut encore considéré le montant alloué pour la main d'oeuvre familiale qui est en moyenne de $290 dans le Québec et qui en réalité n'est pas déboursé.

Ceci explique comment il se fait que, dans les cas où un cultivateur ne retire rien pour son travail personnel, il peut encore mettre un certain montant d'argent en banque même pendant les années mauvaises particulièrement celui qui a peu ou point d'intérêts à rencontrer.

TABLEAU 4.—*Comparaison de quelques item de dépenses dans l'exploitation des vergers.*

	Nouvelle Ecosse	Québec	Ontario
Barils de pommes récoltés à l'acre	81.0	49.4	45.0
Coût des engrais chimiques à l'acre	$11.23	$7.60	$3.31
Coût du matériel d'arrosage à l'acre	10.98	4.48	6.23
Coût de la main d'oeuvre engagée par ferme	760.00	627.00	927.02
Coût de la main d'oeuvre familiale (moins celle de l'exploitant)	187.00	290.00	226.89
Revenu par acre de verger en rapport	132.51	158.00	113.93

On voit dans ce tableau que le rendement à l'acre est beaucoup plus élevé dans la Nouvelle Ecosse que dans le Québec et l'Ontario. Ceci est dû en partie à ce que les vergers sont plus vieux, les arbres plus gros, et en partie à ce que l'on fait l'usage de beaucoup plus d'engrais chimiques. Les méthodes de culture sont aussi différentes; dans la Nouvelle Ecosse et l'Ontario la plus grande partie des vergers sont en culture tandis que dans le Québec la plupart des vergers sont laissés en gazon et l'on y fait l'application d'un paillis autour des arbres, soit en y laissant le foin qu'on coupe soit en utilisant de la paille. Les revenus à l'acre sont sensiblement les mêmes dans les diverses provinces mais l'on peut dire que si les pomiculteurs du Québec obtenaient un rendement aussi élevé que ceux de la Nouvelle Ecosse ils doubleraient leurs revenus. Par contre s'ils obtenaient des prix semblables à ceux que reçoivent les producteurs de la Nouvelle Ecosse, avec un rendement beaucoup plus faible, ils ne pourraient pas tenir longtemps. Il semble donc sage de travailler dans le Québec à augmenter le rendement des vergers par l'application de plus d'engrais chimiques ou par d'autres moyens suggérés par les experts en la matière.

Bien que le rendement, le coût des matériaux d'arrosage et des engrais chimiques à l'acre sur les fermes du Québec et de l'Ontario soient relativement bas, en moyenne, cela ne veut pas dire qu'un bon nombre de producteurs de pommes n'obtiennent pas déjà un bon rendement, qu'ils n'emploient pas suffisamment d'engrais chimiques et qu'ils ne font pas tous les arrosages nécessaires, comme on peut le constater par le tableau suivant.

TABLEAU 5.—*Groupement des 74 fermes du Quebec selon le rendement, le coût des arrosages et des engrais chimiques à l'arpent de verger en rapport.*

NOMBRE DE BARILS A L'ARPENT

Nombre de fermes dans chaque groupe	Moins de 40 barils	De 40 à 50 barils	De 50 à 60 barils	De 60 à 70 barils	De 70 à 80 barils	De 80 à 90 barils	De 90 à 100 barils
	34	11	10	5	7	4	3

COUT DES ARROSAGES A L'ARPENT DE VERGER EN RAPPORT.

Nombre de fermes dans chaque groupe	Moins de $2	De $2 à 4	De $4 à 6	De $6 à 8	De $8 à 10	De $10 et plus
	11	28	22	6	4	3

COUT DES ENGRAIS CHIMIQUES A L'ARPENT DE VERGER EN RAPPORT.

Nombre de fermes dans chaque groupe	Pas d'engrais chimiques	Moins de $3	De $3 à 6	De $6 à 9	De $9 à 12	De $12 à 15	De $15 à 18	De $18 à 21	$21 et plus
	10	12	22	11	7	3	3	3	3

N.B.—Comme il était impossible dans la plupart des cas de connaître sèparèment la quantitè d'engrais chimiques appliquès sur les jeunes vergers et sur les vergers en rapport, il s'ensuit que dans les cas où les jeunes vergers ont une ètendue assez considèrable le montant d'engrais chimiques dèpensè par arpent de verger en rapport semble trop fort.

RESUME DES ARTICLES PUBLIES EN ANGLAIS DANS CE NUMERO

La Maturation des Tissus du Pied et de la Racine Dans le Ble Lors de L'Infection par Ophiobolus Graminis Sacc. H. T. Robertson, Laboratoire fédéral de Pathologie Végétale, Université de l'Alberta, Edmonton.

L'article explique les changements qui se passent lors du vieillissement des tissus du pied chez les plantes de blé Marquis atteintes de la maladie connue sous le nom de "take all". La maladie attaque les plants dans les premiers stages de la croissance. Sous verre, il y a une réduction marquée de l'infection après que les plants de blé sont agés de 40 jours. On pense que l'épaississement des parois cellulaires et les modifications chimiques accompagnant la maturation du pied empêchent le champignon de la pourriture du pied de se développer. Dans le champ, la maladie forme des taches, les plantes les plus courtes se trouvant au centre. L'auteur suggère que l'attaque la plus viruuente commence à un point central et s'arrête ensuite progressivement du fait que les plantes en vieilissant deviennent capables de résister à l'infection partie du centre et progressant vers l'extérieur.

Divers Facteurs Influencant la Production des Graines de Luzerne (*Medicago Sativa*). V. Engelbert, Collège Agricole de l'Ontario, Guelph, Ont.

L'auteur est d'avis que le climat est le facteur le plus important dans la production des graines de luzerne. Dans les comtés de Wellington et de Peel en Ontario où les recherches furent conduites, les conditions climatériques idéales furent décrites ainsi: "En 1926 on obtient la plus forte récolte de la période et le système des précipitations atmosphériques fut aussi parfait qu'on peut l'espérer dans l'Ontario. Des pluies modérées en mai, suivies de pluies au début de juin fournirent le reste de l'humidité nécessaire sans dépasser la limite désirable à aucun moment. Du 27 juin au 9 juillet on eut une période absolument sèche. En juillet on n'eut que des averses légères suffisantes pour prévenir une sécheresse trop prononcée mais non pour abîmer les fleurs ou provoquer la coulure. Le mois d'août fut très humide, fournissant des conditions idéales pour développer les gousses."

D'après l'auteur, des pluies excessives en juillet semblent être la principale cause des échecs dans ces deux comtés. Un peu de pluie en juillet semble affecter la plante juste assez pour la pousser à la formation de la graine.

Les Besoins en Proteines Poussins en Croissance. Helen I. Milne, Université de l'Alberta, Edmonton, Alta.

Des essais préliminaires ayant montré que les meilleurs résultats étaient obtenus avec un supplément de protéines variant de 30% à 55% une seconde série d'essais fut conduite avec une ration un supplément de protéins de 40% (total des protéines 23.32%). Les résultats obtenus furent entièrement satisfaisants et bien meilleurs que dans le cas des rations contenant un supplément de protéines de 20% ou de 60%. De bons résultats furent obtenus dans un poulailler avec un supplément de protéines décroissant de 60% la première semaine jusqu'à 10% la sixième semaine. Deux poulaillers élévés avec une ration nutritive contenant une forte proportion de maïs jaune et un supplément de protéines de 25% donnèrent aussi de bons résultats. Pour tous les poulaillers de la seconde série, le supplément de protéines contenait 50% de farine de sardines, 25% de déchets de boeuf et 25% de lait écremé en poudre. Le rapport du calcium au phosphore fut maintenu constant à un niveau d'environ 3/1.

CURRENT PUBLICATIONS

74. The Waste Products of Agriculture. Albert Howard, C.I.E., M.A. and Yeshwant D. Wad. M.Sc. Institute of Plant Industry, Indore, India. Oxford University Press, University Avenue, Toronto 2. Price $2.25.

One is impressed with the sharp contrast between Oriental and Occidental conditions in reading this thesis on the manufacture of humus in India. Whether or not the process could be adapted to Canada would depend upon local conditions. The authors give a very clear account of the methods used at the Institute of Plant Industry at Indore. Using cheap labour, compost is produced from manure, waste vegetable products, chemicals and bacteria. It is claimed that this product has three times the value of ordinary manure. It is suggested that the mechanical genius of Western countries may substitute equipment to be used to offset the cheap labour factor in India. The book is well written and exceedingly well illustrated and should be of interest to chemists, bacteriologists, and field husbandmen. The factor of rural sanitation is also a recommendation for the system.

75. A Biographical List of the Entire Domain of Agricultural Chemistry. Edited by Dr. H. Niklas and Dr. A. Hock with Dr. F. Czibulka as compiler. Published by the Agricultural-Chemical Institute Weihenstephan of the Technical University Munich. Volume I, Soil Science. Price RM 40. Volume II, Soil Analysis. Price RM 12.

These two Volumes, the first of six covering the whole field of agricultural chemistry, should find a place on the shelves of all agricultural libraries and soil chemistry libraries in Canada. The remaining Volumes to be published are as follows: Volumes III and IV, Plant Nutrition and Fertilization; Volume V, Agricultural Bacteriology; and Volume VI, Animal Nutrition.

Volume I, on Soil Science, contains 1008 pages of titles divided into the following heads: 1. General Literature; 2. Formation of Soils; 3. Soil Chemistry; 4. Soil Physics; 5. Relationships between Soil and Surroundings; 6. Division of Soils, i.e. Classification; 7. Soils in Different Countries; 8. Composition of Soils, Rocks and Minerals. It contains a Table of Contents in English and a Subject Index in English. There is also a complete Author Index. The titles of papers are usually given in their own language, although some have been translated into German. The work will be found especially valuable to Canadian chemists on account of its extensive European bibliography.

Volume II on Soil Analysis consists of 200 pages including the features mentioned above. It is divided into the following main sections: Chemical Soil Analysis, Physical Soil Analysis, Microbiological Soil Analysis, Microscopic Soil Analysis and Mineralogical Soil Analysis.

Orders for these books may be placed through the Canadian Society of Technical Agriculturists, although the usual 15% discount will not be guaranteed.

76. Russia as a Producer and Exporter of Wheat—Wheat Studies of the Food Research Institute, Volume 8, Numbers 5 and 6, March and April, 1932, Stanford University, California, $2.00.

This publication is one of the series which the Food Research Institute has contributed during the past few years on various phases of the wheat situation. Presenting as it does up-to-date information on the situation in Russia it will naturally be of particular interest to producers in Canada and other wheat exporting countries. In the summary of the Report we find the following:

"Soviet Russia seems unlikely, in the next few years at least, to recover the pre-war position of the Russian Empire as an exporter of wheat. Russia's domestic requirements for wheat have increased, and are increasing steadily, with the growth of population and the limited expansion of rye production. The large wheat exports of 1930-31 were made possible by exceptionally high yields per acre and rationing of domestic consumption; and large as they were, they were small in contrast with pre-war exports in years of high yields. As before the war, the volume of exports will fluctuate widely from year to year. Sizable exports are to be anticipated in years of high yields, but not in years when the yields are average or low.

Broadly speaking, exports can attain the pre-war level only if acreage and/or yield per acre can be increased more rapidly than the population grows. But expansion of the

total crop area must take place principally on relatively poor-quality land in Asiatic Russia, and through diversion of fallow land to crops".

This review, besides discussing the present situation in Russia, gives sufficient of the agrarian development, agricultural organization and practice, the Soviet agricultural policy, and similar information to enable the reader to obtain a very fair picture of what has happened and what is taking place. The publication presents a considerable amount of statistical data which will be of value to all those interested in the production and marketing of wheat. -J.F.B.

77. The Canadian Grain Trade. Dr. D. A. MacGibbon. Published by the Macmillan Company of Canada, Ltd., Toronto. $4.00.

In his preface Dr. MacGibbon states that it is his "hope that the present study, by explaining the technique of the trade, will make it possible for any person to discover their bearings with questions that arise in connection therewith, without too much difficulty. The work aims to present a comprehensive picture of the Canadian grain trade as it exists at the present time." To say that the author had succeeded in his undertaking would be very mild praise. He has succeeded admirably and the value of his contribution to the understanding of the Canadian grain trade can hardly be estimated. A great deal of historical material is included and the present system is reviewed in the light of many of the factors which have gone into its development.

The first four chapters deal with the early growing of wheat in Canada, the opening up of the West and the rapid development of the last few years. Part Two covers the technique of the trade, including a great amount of detail on elevator systems, transportation, inspecting and weighing, shipping records, the grain exchange and grain companies, the co-operative movement, the financing of the grain trade, and federal control of the grain trade. Part Three deals with the milling industry in its relations to the grain trade, the export market for Canadian grain and the underlying conditions of production. An Appendix discusses the Hudson Bay route.

A feature of the book which will appeal to the technical agriculturist is the impartial judgment concerning such points as the holding policy of the Wheat Pools, the future of the Pools, the possibility of Federal control, and the Hudson Bay route. So much propaganda has appeared of late regarding these moot questions that one should study Dr. MacKibbon's book thoroughly before attempting to form opinions. The author's status as Assistant Commissioner, Board of Grain Commissioners and a former member of a Royal Commission inquiring into the grain trade, in addition to his standing as an economist, makes his book a standard work on the subject. -H.L.T.

78. The Journal of Animal Ecology. Published by the British Ecology Society. Volume I, Number 1, May 1932.

The increasing number of papers dealing with animals submitted for publication in the Journal of Ecology, caused the British Ecological Society to consider the establishment of a separate journal. It is announced that the "Journal will publish primarily papers dealing exclusively with animals (such as population and migration studies and like problems) and with methods of research having reference primarily to animals". There will be two numbers each year, published in May and November, and the journal will be printed and distributed by the Cambridge University Press, with Mr. Charles Elton as Editor and Mr. A. D. Middleton as Assistant Editor. Subscription to non-members of the Society is 30 shillings per annum, payable in advance. Subscription may be sent direct to the Cambridge University Press, Fetter Lane, E.C.4, or to the Canadian Society of Technical Agriculturists, Ottawa.

The general articles in the first issue are concerned mainly with insects and birds. A list of notices of publications on Animal Ecology is given which includes about 40 items dealing with several aspects of Ecology. This number of the Journal may be secured for examination from the Main Library, Department of Agriculture, Ottawa.

79. Proceedings of the American Society of Horticultural Science, 1931, Volume 28.

This volume of 675 pages includes over 150 papers on Horticultural Science delivered at the 28th annual meeting of the Society held in New Orleans, Louisana, December 28th, 29th, and 30th, 1931. The papers cover practically the whole range of Horticulture and come from United States institutions and organizations. A casual examination failed to reveal any papers by Canadian horticulturists, although the names of several appear on the various committees. This and other volumes may be borrowed from the Dominion Department of Agriculture Library.

80. The Relative Milling and Baking Quality of Western Canadian Spring Wheat Varieties. By J. G. Malloch, W F. Geddes and R. K. Larmour. Contribution from the Department of Field Crops, University of Alberta, Edmonton; Department of Agricultural Chemistry, University of Manitoba, Winnipeg;and Department of Chemistry, (supported by the Saskatchewan Agricultural Research Foundation), University of Saskatchewan, Saskatoon; covering an investigation under the Associate Committee on Grain Research of the National Research Council of Canada. Issued as Paper No. 32 of the Associate Committee on Grain Research. Canadian Journal of Research, Volume 6, Number 4, April, 1932.

To maintain the quality of Canada's export wheat it is essential that only high quality varieties should be grown. To supply information on which a choice of varieties may be based, a co-operative study was made of the milling and baking quality of 25 varieties of spring wheat now grown in western Canada. Samples were grown in adjacent plots by the Dominion Experimental Farms and Universities in Manitoba, Saskatchewan and Alberta in 1928, 1929 and 1930. Only samples which were sound enough to be placed in the statutory grades by official inspectors were used. Part of each sample was milled and baked in each of the three co-operating laboratories. Four baking formulas were used. The varieties were classified on the bases of loaf volume, texture, crumb colour, general appearance of loaf,absorption, and yield of straight flour. These classifications were combined to give classifications for baking quality and milling quality and finally for suitability for export and domestic milling. The last classification is given in Table XXVII and is, briefly, as follows:

1. Varieties which are entirely satisfactory: Reward, Ceres, Marquis, Pioneer, Red Fife, Renfrew, Red Bobs 222, Supreme.

2 Varieties which are fairly satisfactory: Early Red Fife, Ruby, Early Triumph.

3. Varieties which are unsatisfactory: (a) White Wheats; Quality, Axminster, Hard Federation; (b) Varieties differing from Marquis in milling characteristics: Garnet, Kota; (c) Varieties inferior to Marquis in baking characteristics: Garnet, Parker's Selection, Brownhead, Huron, Kitchener, Preston, Marquillo.

4. Varieties which are very unsatisfactory: Early Prolific, Dicklow, Vermilion.

81. Inheritance of Resistance to Fowl Paralysis. By Jacob Biely,Elvira Palmer and V. S. Asmundson. Contribution from the Departments of Poultry Husbandry and Bacteriology, University of British Columbia, Vancouver, with Financial assistance from the National Research Council of Canada. Canadian Journal of Research, Vol. 6, No. 4, April, 1932.

Data are presented on two groups of thirty chicks each, hatched from a susceptible and an apparently resistant flock. There was a significant difference in the incidence of fowl paralysis and lymphomatous tumours in these two groups. This is interpreted to mean that there is an inherent difference in susceptibility and resistance to fowl paralysis and lymphomatous tumors.

82 Comparison of Efficiency of the Rapid Whole Blood Agglutination Test with the Serum Agglutination Test for Pullorum Disease. By Jacob Biely and William Roach. Contribution from the Departments of Bacteriology and Poultry Husbandry, University of British Columbia, Vancouver, with financial assistance from the National Research Council of Canada. Canadian Journal of Research, Vol. 6, No. 4, April, 1932.

The results obtained with the rapid whole blood agglutination test for pullorum disease, applied in the field, agree closely with the results secured with the rapid serum agglutination test, applied in the laboratory.

The accuracy of the diagnosis was found to depend upon the training and experience of the technician. When the whole blood agglutination test was applied by inexperienced persons, the results obtained differed from the laboratory test by 12% as compared with a difference of 1.3% when the whole blood agglutination test was applied by an experienced technician.

The rapid whole blood agglutination test was found to lend itself very readily to practical application in the field. The extremely low cost makes feasible the application and repetition of the test on a large scale.

Since it is known from previous work that one agglutination test will not eliminate all carriers of pullorum diseases, the rapid whole blood agglutination test should be applied several times a year until at least two successive negative tests are obtained on each bird of the flock.

CONCERNING THE C.S.T.A.

C.S.T.A. CONVENTION, WINNIPEG, JUNE 15th TO 18th

Final arrangements have been completed for holding what is expected to be one of the most important conventions of the C.S.T.A. ever held. At various times during the existence of the Society, it has found itself facing difficult conditions which called for sacrifice and support on the part of the members. Such conditions face us at the present time. There is a growing feeling that as a Society we have a wider responsibility for the welfare of Canadian agriculture than we have heretofore accepted and it is possible that out of the reports and resolutions presented to this convention, there will be pointed out a way for the widening of the influence of the Society.

Members who desire further information on the convention are requested to turn to the programme printed at the back of the May issue. This programme stands as it is with the minor corrections given below for the Soils Group and the Horticulture Group. In addition to the speakers listed, the Hon. Robert Weir, Minister of Agriculture for Canada, has intimated that he expects to be present for part of the Convention.

C.S.T.A. HORTICULTURAL GROUP

Since the original programme for the C.S.T.A. Convention was published, the Horticultural Group has decided to transfer the business meeting to Wednesday morning, June 15th, at 9.30 a.m. and the general meeting to Thursday afternoon, June 16th, at 1.30 p.m. The papers listed for Wednesday evening will be given on Thursday afternoon also. Members of the Manitoba Horticultural Association are invited to attend the afternoon session.

SOILS GROUP, C.S.T.A.

Since publishing the programme for the Winnipeg Convention, three additional papers have been submitted to the Soils Group. These are as follows: "The Fundamental Bases of the Evolution of the Soil", by Dr. C. C. Nikiforoff, U.S. Bureau of Chemistry and Soils; "Preliminary Studies of the Vertical Distribution of Easily Soluble Phosphates in Some Representative Ontario Soils", by H. W. Lohse and G. N. Ruhnke, Ontario Agricultural College, Guelph, Ont.; and "Good and Poor Strains of *Rh. trifolii*", by Dr. W. G. Laird, University of British Columbia, Vancouver, B.C.

In addition to a good attendance from the Soils Divisions of several of the Canadian Universities, a number of members of the staff of the Soils Department of the University of Minnesota are expected to be present at the C.S.T.A. Convention and the meeting of the C.S.T.A. Soils Group.

NOTICE TO ANIMAL HUSBANDRY MEN

Attention is drawn to the meeting of the Eastern Canada Society of Animal Production, which will take place in Ottawa on July 5th and 6th. This Society, under the Chairmanship of Professor J. C. Steckley, is enthusiastic in promoting this get-to-gether of those interested in livestock, which will be held at the Chateau Laurier Hotel commencing on the afternoon of July 5th. Lectures and addresses will be given covering the main phases of the livestock industry and an inspection tour will be made to the Central Experimental Farm and to the Research Laboratory of the Health of Animals Branch. All those connected with or engaged in investigational, educational, and administrative capacities relative to livestock and poultry should find the meeting refreshing and interesting, and are cordially invited to attend.

C.S.T.A. ELECTIONS

Ballots for the election of the officers of the C.S.T.A. for the year 1932-33 were opened on April 20 at the Society headquarters. A total of 804 members voted, with the following results: President, Dr. G. I. Christie, President, Ontario Agricultural College, Guelph, Ont., Vice-Presidents, Hon. Dr. J. A. Godbout, Minister of Agriculture, Quebec, P.Q., and L. H. Newman, Dominion Cerealist, Central Experimental Farm, Ottawa, Ont., Honorary Secretary, George H. Clark, Seed Commissioner, Ottawa.

THE TECHNICAL AGRICULTURIST AND RESEARCH SCIENTIST

The following tribute appeared in a recent issue of "Weekly Grain Market Features", published by the Searle Grain Co. Ltd. with headquarters at Wininpeg. In this tribute we heartily concur.

"A noted Canadian grain exhibitor is reported in the press to have recently made a statement which suggested that the work now being performed by the Rust Research Scientists in their efforts to produce a good milling variety of wheat that would be rust-resistant was "A wildgoose chase and a waste of good time and money".

The Searle Grain Company, as a result of their experience in handling and marketing Canadian grain over a long term of years, are much impressed with the value to the Canadian farmer of the superior quality of Canadian wheat and of the high yield per acre of Canadian farms compared with the lower yields of competing wheat exporting countries.

Study of the reasons for these advantages shows most conclusively that in great measure they are a direct result of the skilled technical work of the scientific agriculturist and research worker such as are associated with the Canadian National Research Council, the Dominion Experimental Farms, the various Provincial Universities and Agricultural Colleges and the Federal and Provincial Departments of Agriculture.

The Searle Grain Company have calculated that the premium which has been paid for Canadian wheat on the world's markets in excess of the payments made for Argentine, Russian and other wheats, has amounted to the vast sum of two hundred million dollars since Canada first started to export wheat to the markets of the world. (The premium at this date is 15 cents a bushel.)

These substantial sums of money are reflected back, in full, to the Canadian farmer by the Grain Trade, but these premiums are only made possible in the first place by the skill and untiring zeal and work of the gentlemen who have been mentioned,—the Scientific Agriculturists and Research Workers.

Simple calculation will show that the money spent in the cost of the upkeep of the Institutions mentioned has been returned in extra profits to the Canadian farmer, and so to the benefit of the whole country a great many times over. It would, in our opinion, be a sad outlook for the future of the Canadian farmer, should the work of the Agricultural Scientist and of the Institutions for which he labors be in any way curtaoinled or hampered, or even suffer from lack of encouragement."

NOTES AND NEWS

G. A. Ledingham, (Saskatchewan '27) is now located at the Horticultural Experiment Station, Vineland, Ontario.

A. Georges Gilbert, (Laval '23) was married on May 17 to Miss Lillian Bélanger, of Campbell's Bay, P.Q. They have taken up residence at 80 Byron Avenue, Ottawa, Ont.

J. R. Pelletier, (Laval '27) has been promoted from the position of Experimental Farm Assistant, Grade 2, Experimental Station, Farnham, P.Q., to Experimental Farm Assistant, Grade 3, Experimental Station, Ste. Anne de la Pocatière, P.Q.

Dr. J. E. Lattimer, (Wisconsin '26) Head of the Department of Agricultural Economics, Macdonald College, has sailed for England to spend a few months in economic studies in Europe.

A. McGugan, (Toronto '26) is now manager of the Clinton Creamery, Clinton, Ont.

Reginald Barbin, (Laval '13) has changed his address to 112 Richelieu Street, St. Jean, P.Q.

Ernest Giasson, (Laval '31) has changed his address to 112 Richelieu Street, St. Jean, P.Q.

Trueman Stevenson, (Saskatchewan '23), who has just returned from postgraduate work leading to his Doctor's Degree at the University of Minnesota, has been appointed Agrostologist Specialist at the Dominion Forage Crops Laboratory, Saskatoon, Sask.

H. O. Taylor, (Manitoba '32) has changed his address to 213 Perth Avenue, Winnipeg, Man.

D. W. Basarab, (Manitoba '32) has returned to Sifton, Man.

N. M. MacGregor, (Manitoba '32) has returned to St. Lazare, Man.

The following members of the British Columbia Local of the C.S.T.A. have received their M.S.A. degrees at the recent convocation of the University of British Columbia: R. J. N. Mayers, (British Columbia '30), E. E. Peden, (British Columbia '30), J. J. Woods, McKenzie, (British Columbia '30), E. E. Peden, (British Columbia '30), J. J. Woods, (British Columbia '23), W. H. Hill, (Toronto '16).

P. Stobbe (Manitoba '32) has been appointed Assistant in the Agronomy Department, Macdonald College, P.Q.

SELECTED LIST OF ACCESSIONS TO THE LIBRARY OF THE DOMINION DEPARTMENT OF AGRICULTURE

Members of the C.S.T.A. may borrow these postfree by addressing a request to the Librarian, Department of Agriculture, Ottawa.

Adams, Leonard P. Agricultural depression and farm relief in England, 1813-52. London, P. S. King & son, ltd. 1932. 191 p.

American institute of cooperation. American cooperation; a collection of papers and discussions comprising the 7th summer session . . . Washington, D.C. 1931. 2 vols.

American society for horticultural science. Proceedings. Vol. 28, 1931. Geneva, N.Y.

Beeman, H. N. Veterinary obstetrics and zootechnics. Washington, D.C. American remount association, 1932. 131 p.

Bowen, J. T. Refrigeration in the handling, processing, and storing of milk and milk products. Washington, D.C. 1932. 58 p. (U.S. Dept. of agriculture. Miscellaneous publication 138).

British association for the advancement of science. Report. Vol. 100, 1931. London, 1932.

British gladiolus society. The gladiolus annual, 1932. Granleigh, England, 1932. 108 p.

Broomhall's corn trade year book. Liverpool, Northern publishing co. 1931. 152 p.

Brues, C. T. and Melander, A. L. Classification of insects; a key to the known families of insects and other terrestrial Arthropods. Cambridge, Mass. 1932. 672 p. illus. (Harvard college. Museum of comparative zoology. Bulletin Vol. 73).

Burns, W. A. Practical sheep husbandry. Chicago, 1931. 96 p. il.

Canada. Dominion bureau of statistics. Production and distribution of raw wool in Canada, 1931. Ottawa, 1932. 9 p. mimeo.

——— Trade of Canada . . . Calendar year 1931. Ottawa, 1932. 434 p.

Canada. Parliament. Select standing committee on agriculture and colonization. Evidence on beet sugar industry. Ottawa, 1932. 6 pts.

——— Evidence on Garnet wheat grading. Ottawa, 1932. 8 pts.

Canadian boys' & girls' club news, Vol. I. No. 1, April 1932. Ottawa.

Canadian gladiolus society. The 1932 Canadian gladiolus annual. No. 9. Guelph, Ont. 1932. 135 p. il. col. plates.

Canadian grain trade year book. Vol. 11, 1930-31. Winnipeg, W. Sanford Evans statistical service, 1931. 115 p.

Carmack, E. G. Comp. price sources, 1931. Washington, D.C. 1931. 320 p. (Issued by the U.S. Dept. of commerce).

Carr, G. J. International marketing of surplus wheat. Washington, D.C. 1932. 28 p. (U.S. Dept. of commerce. Trade promotion series. No. 130).

Charbonnel, G. and others. Guide de l'eleveur et des syndicats d'elevage. Troyes, Impr. J. L. Paton, 1931. 199 p. il.

Claassen, C. J. Making farms pay; a narrative of personal experiences in managing 1000 farms. New York, Macmillan co. 1931. 126 p. il.

Congrès international de pathologie comparée. 2e, Paris, 1931. Paris, Masson & cie. 1931.

Cunningham, G. C. The rust fungi of New Zealand . . . Dunedin, N.Z. 1931. 261 p. il.

Cutler, G. H. A modification of the Saunders' test for measuring "quality" of wheats for different purposes. (Reprinted from Journal of the American society of agronomy. Vol. 23, 1931).

Deakin, Alan. Cases of extreme sexual infantilism in the sow. (Reprint from Anatomical record. Vol. 51, Jan. 1925. pp. 361-68. Plates).

Doane, C. F. Varieties of cheese: descriptions and analyses. Washington, D.C. 1932. 67 p. (U.S. Dept of agriculture. Bulletin 608. rev. ed.).

Dyer, B. W. & co. The sugar index for 1931. New York, 1931. 208 p.

Economic history. Vol. II. No. 7, Jan. 1932. London, Macmillan, 1932. Faraday society. Photochemical processes; a general discussion. London, 1931. pp. 355-574.

France Office national sériocicole. Le ver à soie du murier. Valence, 1931. 32 p. il. col.

Frost, W. D. and Hankinson, Hazel. Lactoacidophilus; an annotated bibliography to 1931. Milton, Wis. Davis-Greene corp. 1931. 160 p.

Gratton, Adhémar. Guide pratique d'alimentation rationnelle des volailles. Montréal, Coopérative fédérée de Québec, 1932. 60 p.

Gt. Brit. Ministry of agriculture & fisheries. Cheese-making. London, 1932. 62 p.

——— Some diseases of rabbits. London, 1931. 12 p. (Bulletin 14).

Hale, J. D. The identification of woods commonly used in Canada. Ottawa, 1932. 48 p. il. (Canada. Forest service. Bulletin 81).
Hill nursery co. Hill's evergreens. Dundee, Ill. 1931. 64 p. illus. col. plates.
Hitchcock, A. S. Field work for the local botanist. Washington, D.C. 1931. 58 p.
Holland county council. Notes on the cultivation of bulbs. Kirton, Lincs. 1932. 21 p.
Holman, R. A. Forty years of co-operation; a history of the first successful co-operative grain elevator in the United States. Rockewell, Iowa, 1931. 62 p. il.
Holmes, C. L. Farm production costs as affected by mechanical farm equipment. Washington, D.C. 1931. 12 p. mimeo.
Imperial bureau of plant genetics. Account of the research in progress in the British Empire. Cambridge, 1932. 91 p. mimeo.
——— Research on forage crops in Soviet Central Asia, with special reference to Turkestan lucerne. Aberystwyth, 1932. 32 p. Bibl. pp. 30-32.
International society of soil science. Sixth commission. Transactions, edited by Otta Fauser. Groningen, 1932. 341 p.
Johnson, E. C. Some facts on farm mortgage foreclosures in Minnesota. St. Paul, Minn. 1931. 5 p. mimeo. (Minnesota farm business notes. No. 105).
The journal of animal ecology. Vol. I. No. 1, May 1932. Cambridge. University press, 1932. 100 p. illus.
Kalé, G. Recherches anatomiques, chimiques, physiologiques, et génétiques sur Triticum vulgare Host. Toulouse, Imprimerie régionale, 1931. 231 p. il. Bibl. pp. 219-29.
Kansas City. Board of Trade. The government's experiment in wheat. Kansas City, Mo.
Kenya. Dept. of agriculture. Report on the 1931 locust invasion of Kenya. Nairobi, 1931.
Kihara, Hitoshi & others. A list of chromosome-numbers of plants cultivated in Japan. Tokyo, 1931. 330 p.
Leathersellers' company. Report on warble fly campaign, 1931. London, 1932. 32 p. Bibl. pp. 31-32.
Liaison committee of rural women's and homemakers' organizations. What the countrywomen of the world are doing. London, 1932. 213 p.
Link, George K. K. Market diseases of fruits and vegetables: Potatoes. Washington, D.C. 1932. 62 p. il. col. plates. (U.S Dept. of agriculture. Miscellaneous publication No. 98).
Looker, A. P. Commercial rabbit breeding under Australian conditions. Adelaide, Thornquest press, 1931. 61 p. il.
Margulis, H. H. Contribution à l'étude de quelques problèmes de la chimie du sol; le sol et le calcaire; le sol et la potasse; les sol et les solutions salines. Toulouse, Impr. régionale, 1931. 71 p. Bibl. p. 71.
Maurice, A. Le ragondin. Paris, 1931. 234 p. il. (Archives d'histoire naturelle. VII.).
Metcalf, C. L. Black flies and other biting flies of the Adirondacks. Albany, N.Y. 1932. 78 p. il. (New York state museum bulletin No. 289).
Miège, Em. Contribution à l'étude des plantes fourragères. Rabat, 1931. 32 p. il.
- - - - Enroulement et torsion des feuilles des céréales. Rabat, 1932. 19 p.
——— Etude de quelques caractères des feuilles des céréales. Rabat, 1932. 52 p
Millers' national federation. Flour package laws; a summary of the requirements in the various states. Chicago, 1931. 8 p.
Morse, J. W. Soybean utilization. Washington, D.C. 1932. 28 p. illus. (U.S. Dept. of agriculture. Farmers' bulletin 1617. Rev. ed.).
Murray, Sir J. A. H. and others, editors. New English dictionary on historical principles. Oxford, Clarendon press, 1888-1928. 20 vols.
National dairy council of Canada. Annual reports, 1931. Ottawa, 1932. 31 p.
National industrial conference board, inc. The cost of living in the United States, 1914-30. New York, 1931. 170 p.
National rose society. The rose annual, 1932. Croydon, 1932. 257 p. illus. col. plates.
New South Wales. Dept. of Agriculture. The dairy manual. Sydney, 1932. 63 p.
Nickerson, Dorothy. Application of color measurement in the grading of agricultural products; a preliminary report. Washington, D.C. 1932. 36 p. mimeo. (At head of title: Bureau of agricultural economics).
Parker, J. R. and others. How to control grasshoppers in cereal and forage crops. Washington, D.C. 1932. 23 p. il. (U.S. Dept. of agriculture. Farmers' bulletin 1691).
Pentz, J. A. Agricultural grasses of South Africa and management of their pastures. Pretoria, 1932. 23 p. il. (South Africa. Dept. of agriculture. Bulletin 106).

Petropavlovsky, M. T. Cultivated oats of U.S.S.R. Leningrad, 1931. 139 p. (Bulletin of applied botany, of genetics and plant breeding. Supplement 45. (English summary).

Radnor, Earl of. The organisation and expansion of the pig industry. (Journal of the farmers' club, London, England. April 1932).

Repony, D. When and how we will get out of this depression. Clifton, N.J. 1932. 61 p.

Rothamsted experimental station. Mechanization and British agriculture. . . . Harpenden, 1932. 55 p. (Rothamsted conferences XIV.).

Shorthorn society of Great Britain & Ireland. Shorthorn breeders' guide, 1932. London, 1932. 230 p. il.

Shutt, Donald B. Control of rancid, fruity, and unclean flavor and mottled color in Ontario Cheddar cheese. Toronto, 1932. 11 p. (At head of title: Ontario. Dept. of agriculture).

Snyder, L. L. The hawks and owls of Ontario. Toronto, 1932. 48 p. il. (Royal Ontario museum of zoology. Handbook no. 2).

Steckley, J. C. Draft horses. Toronto, 1932. 36 p. il. (Ontario. Dept. of Agriculture. Bulletin 365).

Tocher, J. F. What is probable error? London, 1931. 63 p. Toronto. University. Contributions to Canadian economics. Vol. 4. Toronto, 1932. 120 p.

U.S. Dept. of agriculture. The safe use and storage of gasoline and kerosene on the farm. Washington, D.C. 1932. 14 p. il. (Farmers' bulletin 1678).

U.S. Dept. of Commerce. Commerce year book, 1931. Vol. II. Foreign countries. Washington, D.C. 1932. 743 p. map.

U.S. Federal board for vocational education. Organization and teaching procedure to be followed in evening agricultural schools on the marketing of wool and mohair. Washington, D.C 1932 11 p. (Monograph 15). Bibl. pp. 10-11.

United States live stock sanitary association. Proceedings. Vol. 35. 1931. Chicago, Ill. 1931. pp. 289-531.

Wadham, S. M. Some economic aspects of grazing and pasture management in Australia. Melbourne, University press, 1931. 20 p.

Wheat studies. Russia as a producer and exporter of wheat. (Vol. 8, Nos. 5-6, March & April 1932. Wheat studies of the food research institute, Stanford University, California.)

——— Survey of the wheat situation, Dec. 1931 to March 1932. (Vol. 8 no. 7, May 1932).

Wickens, D. L. Farm mortgage credit. Washington, D.C. 1932. 101 p. (U.S. Dept. of agriculture. Technical bulletin 288). Bibl. pp. 100-101.

Winchell, C. M. Home economics for public school administrators. New York, Teachers college, Columbia university, 1931. 151 p.

Wyatt, F. A. & others. Soil drifting and its control. Edmonton, 1932. 26 p. il. (Alberta University. College of agriculture. Circular 13).